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# REPORT FOR CONSULTATION ON THE METROPOLITAN PHILADELPHIA INTERSTATE AIR QUALITY CONTROL REGION (PENNSYLVANIA NEW JERSEY-DELAWARE)

National Air Pollution Control Administration
Washington, D. C.

October 1968

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
U. S. Public Health Service
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration
October 1968

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## PREFACE

The Secretary, Department of Health, Education, and Welfare, is directed by the Air Quality Act of 1967 to designate "air quality control regions" to provide a basis for the establishment of air quality standards and the implementation of air quality control programs. In addition to listing the major factors to be considered in the development of region boundaries, the Act stipulates that the designation of a region shall be preceded by consultation with appropriate State and local authorities.

The National Air Pollution Control Administration, DHEW, has conducted a study of the Metropolitan Philadelphia urban area, the results of which are presented in this report. The Region* boundaries proposed in this report reflect consideration of all available and pertinent data; however, the boundaries remain subject to revision suggested by consultation with State and local authorities. Formal designation will be withheld pending the outcome of that meeting. This report is intended to serve as the starting point for the consultation.

The Administration is appreciative of assistance received either directly during the course of this study or indirectly during previous activities in this three-State area from the official air pollution agencies of the City of Philadelphia and the States of Pennsylvania,

*For the purposes of this report, the word region, when capitalized, will refer to the Metropolitan Philadelphia Interstate Air Quality Control Region. When not capitalized, unless otherwise noted, it will refer to air quality control regions in general.

New Jersey, Delaware, and Maryland. Useful data was also supplied by the Regional Conference of Elected Officials, the Delaware Valley Citizens' Council for Clean Air, the Delaware Valley Regional Planning Commission, the Salem County Planning Board, the New Castle County Land Use and Transportation Program, the New Castle County Department of Planning, the Fels Institute of State and Local Government, and the Regional Science Research Institute of the University of Pennsylvania.

# INTRODUCTION

> "For the purpose of establishing ambient air quality standards pursuant to section 108, and for administrative and other purposes, the Secretary, after consultation with appropriate State and local authorities shall, to the extent feasible, within 18 months after the date of enactment of the Air Quality Act of 1967 designate air quality control regions based on jurisdictional boundaries, urban-industrial concentrations, and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards. The Secretary may from time to time thereafter, as he determines necessary to protect the public health and welfare and after consultation with appropriate State and local authorities, revise the designation of such regions and designate additional air quality control regions. The Secretary shall immediately notify the Governor or Governors of the affected State or States of such designation."
>
> Section 107 (a) (2), Air Quality Act of 1967

## THE AIR QUALITY ACT

Air pollution in most of the Nation's urban areas is a regional problem. Consistent with the problem, the solution demands coordinated regional planning and regional effort. Yet, with few exceptions, such coordinated efforts are notable by their absence in the Nation's urban complexes.

Beginning with the Section quoted above, in which the Secretary is required to designate air quality control regions, the Air Quality Act presents an approach to air pollution control involving closely coordinated efforts by Federal, State, and local governments, as shown in Figure 1. After the Secretary has (1) designated regions, (2) published air quality criteria, and (3) published corresponding documents on

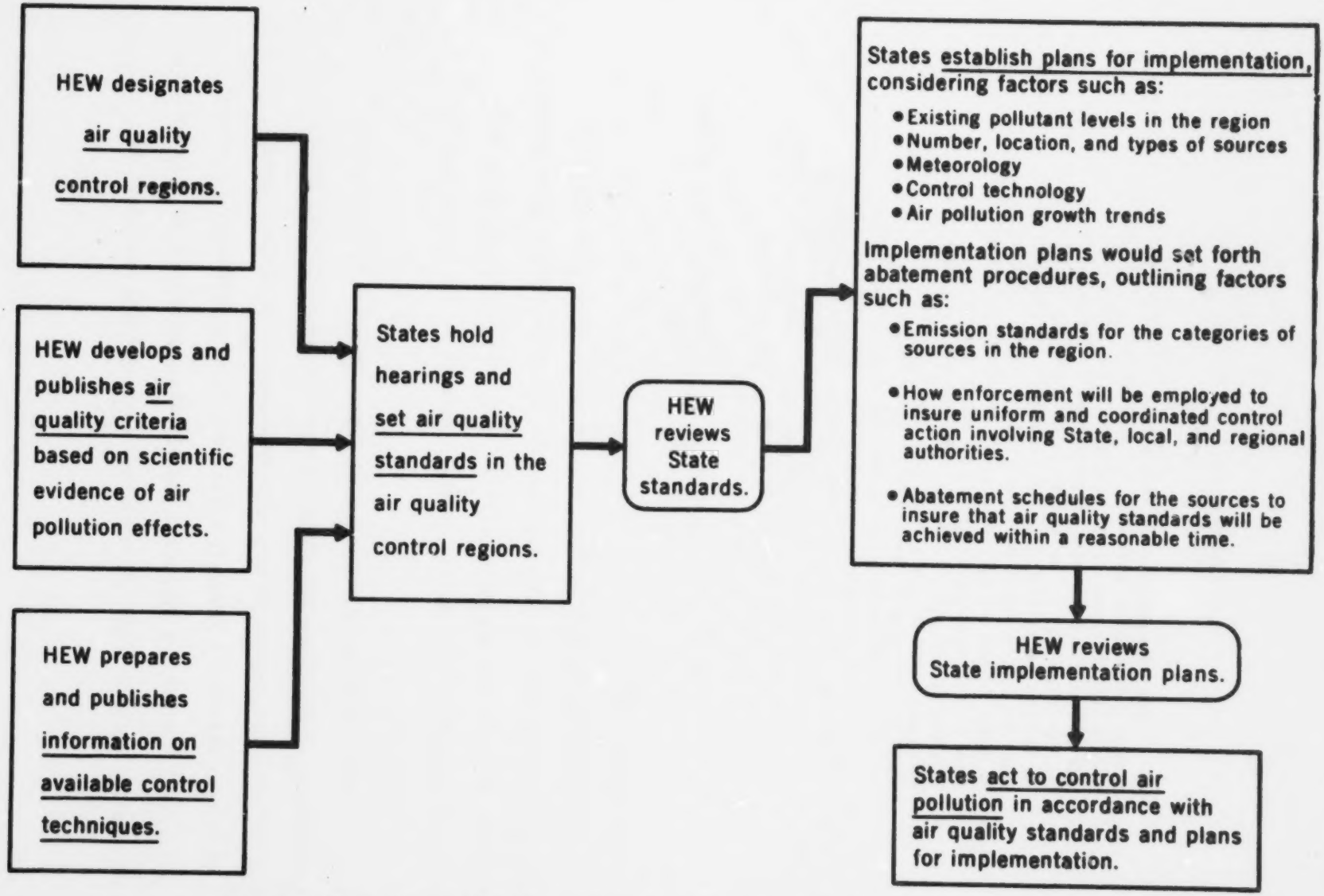
HEW designates air quality control regions.
HEW develops and publishes air quality criteria based on scientific evidence of air pollution effects.
HEW prepares and publishes information on available control techniques.
States hold hearings and set air quality standards in the air quality control regions.
HEW reviews State standards.
States establish plans for implementation, considering factors such as:
• Existing pollutant levels in the region
• Number, location, and types of sources
• Meteorology
• Control technology
• Air pollution growth trends
Implementation plans would set forth abatement procedures, outlining factors such as:
• Emission standards for the categories of sources in the region.
• How enforcement will be employed to insure uniform and coordinated control action involving State, local, and regional authorities.
• Abatement schedules for the sources to insure that air quality standards will be achieved within a reasonable time.
HEW reviews State implementation plans.
States act to control air pollution in accordance with air quality standards and plans for implementation.

Figure 1. Flow diagram for State action to control air pollution on a regional basis.

control technology and associated costs, the Governor(s) of the State(s) must file with the Secretary within 90 days a letter of intent, indicating that the State(s) will adopt within 180 days ambient air quality standards for the pollutants covered by the published criteria and control technology documents and adopt within an additional 180 days plans for the implementation, maintenance, and enforcement of those standards in the designated air quality control regions.

The new Federal legislation provides for a regional attack on air pollution and, at the same time, allows latitude in the form which regional efforts may take. While the Secretary reserves approval authority, the State(s) involved in a designated region assumes the responsibility for developing standards and an implementation plan which includes administrative procedures for abatement and control. Informal cooperative arrangements with proper safeguards may be adequate in some regions, whereas in others, more formal arrangements, such as interstate compacts, may be selected. The objective in each instance will be to provide effective mechanisms for control on a regional basis.

PROCEDURE FOR DESIGNATION OF REGIONS

Figure 2 illustrates the procedures used by the National Air Pollution Control Administration for designating air quality control regions.

A preliminary delineation of the region is developed by bringing together two essentially separate studies - the "Evaluation of Engineering Factors," and the "Evaluation of Urban Factors."

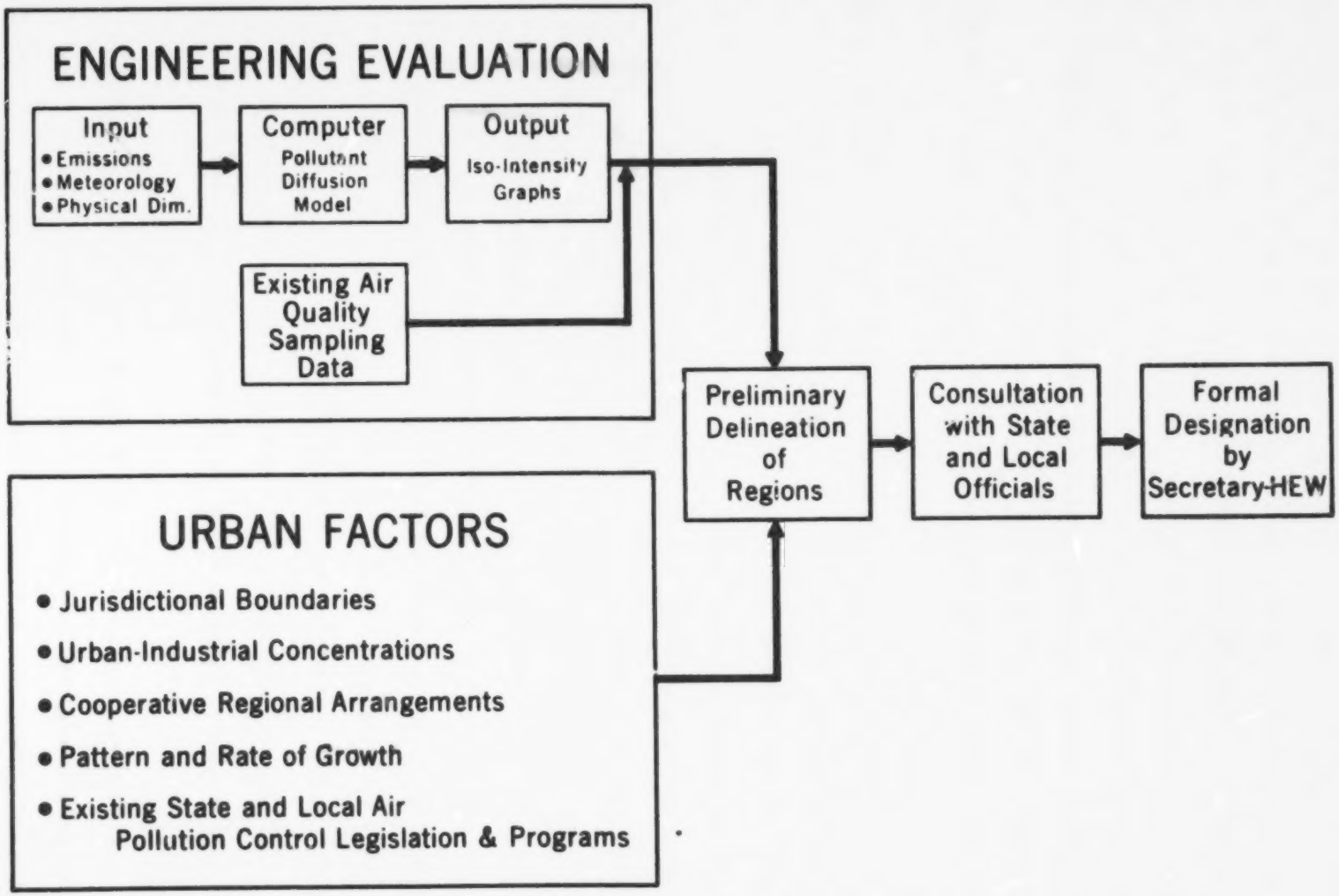


Figure 2. Flow diagram for the designation of air quality control regions.

The study of "Engineering Factors" indicates the location of pollution sources and the geographic extent of serious pollutant concentrations in the ambient air. Pollution sources are located by an inventory of emissions from automobiles, industrial activities, space heating, waste disposal, and other pollution generators. Pollution concentrations in the ambient air are estimated from air quality sampling data and from a theoretical diffusion model. When it exists, air quality sampling data is more reliable than the theoretical diffusion model results since the data is directly recorded by pollution measuring instruments. Unfortunatel , in many cases air quality sampling data is available for only one or two pollutants measured at an insufficient number of locations. The theoretical model is used to supplement inadequate air quality sampling data.

The box labeled "Input" in Figure 2 describes the information required to apply the diffusion model. This information consists of data on the type, quantity, and location of pollution emissions, the average depth of air available for mixing and dilution, the frequency of various wind velocities (direction and speed), and the physical dimensions of the urban area under study. Calculations are made with this information in the next step labeled "Computer." The result, or "Output," of the diffusion model approach is the estimated pattern of air pollution caused by the sources of a given pollutant within the area. These patterns describe the geographic extent of air pollution in the area and serve as a

guide to the appropriate size of the air quality control region. As a whole, the engineering study indicates how large the air quality control region must be in order to encompass most pollution sources and most people and property affected by those sources.

The study of "Urban Factors" encompasses all considerations of a non-engineering nature. It reviews existing governmental jurisdictions, current air pollution control programs, present concentrations of population and industry, and expected patterns of urban growth. Other non-engineering factors are discussed when they are relevant. As a whole, the study of urban factors indicates how large an air quality control region must be in order to encompass expected growth of pollution sources in the future. It also considers which group of governmental jurisdictions will most effectively administer a strong regional air quality control program.

The conclusions of the engineering study are combined with the results of the urban factors study to form the basis of an initial proposal for an air quality control region. As shown in Figure 2, the proposal is then submitted for consultation with State and local officials. After reviewing the suggestions raised during the consultation, the Secretary formally designates the region with a notice in the Federal Register and notifies the governors of the States affected by the designation.

The body of this report contains a proposal for the boundaries of the Metropolitan Philadelphia Interstate Air Quality Control Region and supporting studies on engineering and urban factors. The report

itself is intended to serve as the background document for the formal consultation with appropriate State and local authorities.

## THE PROPOSED REGION

Subject to the scheduled consultation, The Secretary, Department of Health, Education, and Welfare, proposes to designate an air quality control region for the Metropolitan Philadelphia interstate area, consisting of the following jurisdictions:

In The State Of Pennsylvania

Bucks County
Chester County
Delaware County
Montgomery County
Philadelphia County

In The State Of New Jersey

Burlington County
Camden County
Gloucester County
Mercer County
Salem County

In The State Of Delaware

New Castle County

As so proposed, the Metropolitan Philadelphia Interstate Air Quality Control Region would consist of the teritorial area encompassed by the outermost boundaries of the above jurisdictions and the territorial area of all municipalities located therein and as defined in Section 302(f) of the Clean Air Act, 42 U.S.C. 1857h (f). Figure 3 shows the boundaries of the proposed Region and indicates the geographic relationship of the proposed Region to the surrounding areas.

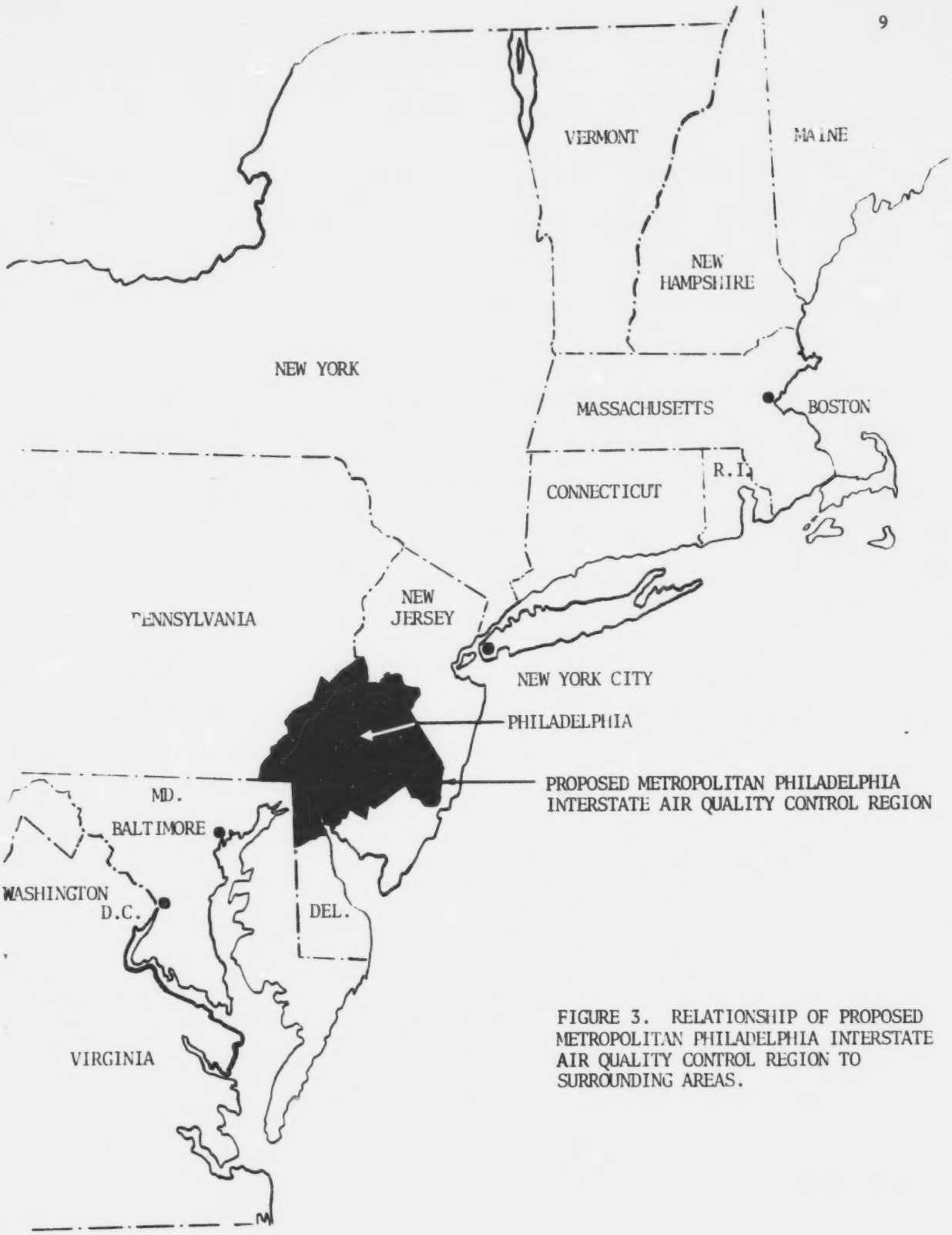


FIGURE 3. RELATIONSHIP OF PROPOSED METROPOLITAN PHILADELPHIA INTERSTATE AIR QUALITY CONTROL REGION TO SURROUNDING AREAS.

## DISCUSSION OF PROPOSAL

There are three major conditions to be met in designating an air quality control region. First, the boundaries should encompass most pollution sources as well as most people and property affected by those sources. Second, the boundaries should encompass those locations where industrial and residential development will create significant air pollution problems in the near future. Third, the boundaries should be chosen in a way which is compatible with and even fosters unified and cooperative governmental administration of the air resource throughout the region.

The Evaluation of Engineering Factors (discussion beginning on page 20 ) was directed toward the first of these condititons and the Evaluation of Urban Factors (page 13 ), the other two. The combination of one Delaware county, five Pennsylvania counties, and five New Jersey counties was common to all three of the stated conditions, leading to the proposal made herein.

With the exception of Chester and Montgomery Counties in Pennsylvania, the remaining nine counties border on the Delaware River. All eleven counties possess a degree of urban and industrial development sufficient to warrant inclusion of at least part of each county in the Region. Consideration of the dispersive nature of the pollutants emitted in the more densely built-up portions of these eleven counties expands the necessary boundary of the Region well out into all but Chester County. Theoretical pollutant levels used as guides to the location of the Region's boundary encompass the easternmost portion

of Chester County, including most of its population and industrial base.

The proposal that the Region include the entirety of these eleven counties satisfies the requirement that the Region be large enough to include the vast majority of pollutant sources affecting the air quality of the urban area. The extension of the Region boundaries to the outer perimeter of the eleven-county group is consistent with the second and third guidelines quoted above. First, this arrangement provides a "buffer-zone" against the expected growth in population in the suburban portions of these counties and the potential increase in pollutant emissions that can be associated with such growth. Second, there are several institutions--both governmental and non-governmental--that involve these same eleven counties. These arrangements, which represent previous identity as a region, should be conducive to compatible and cooperative governmental administration of the air resource once the Region has been established.

As is true of most efforts to draw boundaries around an area to differentiate it from its surroundings, there is always a likelihood of boundary conditions existing or developing. In the case of air quality control regions, such a boundary condition would exist where there are sources of pollution on one side of the region boundary affecting in some real way air quality on the other side of the boundary. This condition will undoubtedly exist along the western boundary of this Region because of the location of Allentown, Bethlehem, Easton, Reading, and Lancaster urban areas in the adjacent counties.

Relocating the boundary would only rarely provide relief from

this condition (especially along the urbanized East Coast). The solution is to be found in the way in which control efforts are implemented following the designation of air quality control region. Consonant with the basic objective of providing desirable air quality within the problem area being designated as an air quality control region, the implementation plan that follows the designation should have provisions for the control of sources located close to but beyond the region boundaries.

The remaining two sections of this report describe the initial evaluation of urban and engineering factors. Each is, as much as possible, independent of the other--both with respect to subject and conclusions. As this discussion has indicated, the final proposal is based upon both studies where there was agreement between them and upon the balancing of the two where the conclusions differed. The Region proposed herein is considered on the whole to be the most cohesive and yet inclusive area within which an effective regional effort can be mounted to prevent and control air pollution in the three-State urban area surrounding Philadelphia.

## EVALUATION OF URBAN FACTORS

In establishing air quality control regions, it is highly desirable to utilize to the fullest possible extent all existing administrative and technical relationships which could be useful in controlling air pollution on a regional basis. The number, variety, and quality of working relationships within the eleven county area* indicates these to be the best possible combination of jurisdictions within which the air pollution problem of this tri-State urban complex should be considered.

There are presently three State agencies, one large municipal agency, and a few smaller county and municipal agencies established to control air pollution within their respective jurisdictions in the Delaware Valley urban area. Of these, the four major administrative agencies responsible for air pollution control are the Delaware Water and Air Resources Commission; the New Jersey State Department of Health; the Pennsylvania Department of Health; and the City of Philadelphia, Department of Public Health. In May 1966, these agencies signed a "Delaware, New Jersey, Pennsylvania Interstate Cooperative Agreement on Air Pollution." A committee created by this Agreement is:

1. Developing and implementing administrative procedures to facilitate the abatement of interstate "point source" air pollution problems.

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*The area includes the following counties: New Castle County, Delaware; Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties in Pennsylvania; Burlington, Camden, Gloucester, Mercer, and Salem Counties in New Jersey.

2. Developing procedures for cooperative action during periods of atmospheric stagnation.

3. Developing procedures to coordinate the activities of the four agencies.

In November 1966, the Mayor of Philadelphia requested the assistance of the Federal Government in improving the City's air pollution control program. In March 1967, a representative group of Federal, State, and local control officials participated in a meeting in Philadelphia to discuss the formation of an expanded regional air quality achievement program for the eleven county Delaware Valley area. The responsibility for developing the operational protocol plus providing the nucleus on-site staff to implement this activity was given to the Abatement and Control Programs, National Center for Air Pollution Control--this Administration's organizational predecessor. Since that time, the Federal air pollution program has been collecting and analyzing air quality data from the eleven county area.

An important general area-wide arrangement is the Regional Conference of Elected Officials (RCEO) which again coincides with the eleven county area. RCEO includes representatives of the elected bodies in all local jurisdictions in the eleven counties. This group has worked together for a variety of planning purposes and recently sponsored a study into methods of controlling air pollution in the area, a regional effort which should not be wasted.

Citizens groups have also been active on a regional basis. The largest of these, the Delaware Valley Citizens' Council for Clean Air, is and has been active in the eleven county area. This group employs a full time Executive Director and maintains an office. It is

conducting a full scale educational and informational campaign throughout the Delaware Valley, and has received wide coverage from the press, radio, and television.

The eleven county area has been the logical focus of planning activities for a variety of planning agencies. The Delaware Valley Regional Planning Commission (DVRPC) was originally formed to plan for the entire eleven counties. While its planning is presently restricted to nine counties (Salem County, New Jersey and New Castle County, Delaware have separate planning functions), there exists much sentiment toward the formation of an agency which will eventually plan for all eleven counties as a unit.

The eleven county area is a combination of the Philadelphia, Trenton, and Wilmington Standard Metropolitan Statistical Areas (Cecil County, Maryland was recently added to the Wilmington S.M.S.A., but has not otherwise become integrated into the region). Utilizing the S.M.S.A. as a basis for delineating a region makes available a much more comprehensive and sophisticated body of data. State, local, and Federal agencies also are usually able to work with a relatively high degree of facility when using the common data unit of the S.M.S.A. as a basis for instituting multi-jurisdictional programs.

The eleven county area also encompasses a cohesive combination of sources and receptors of air pollution. Figure 4 shows the approximate extent of developed land in the eleven county area. (The compilation of the map was made difficult by the lack of a single planning authority for the eleven county area, but the result indicates

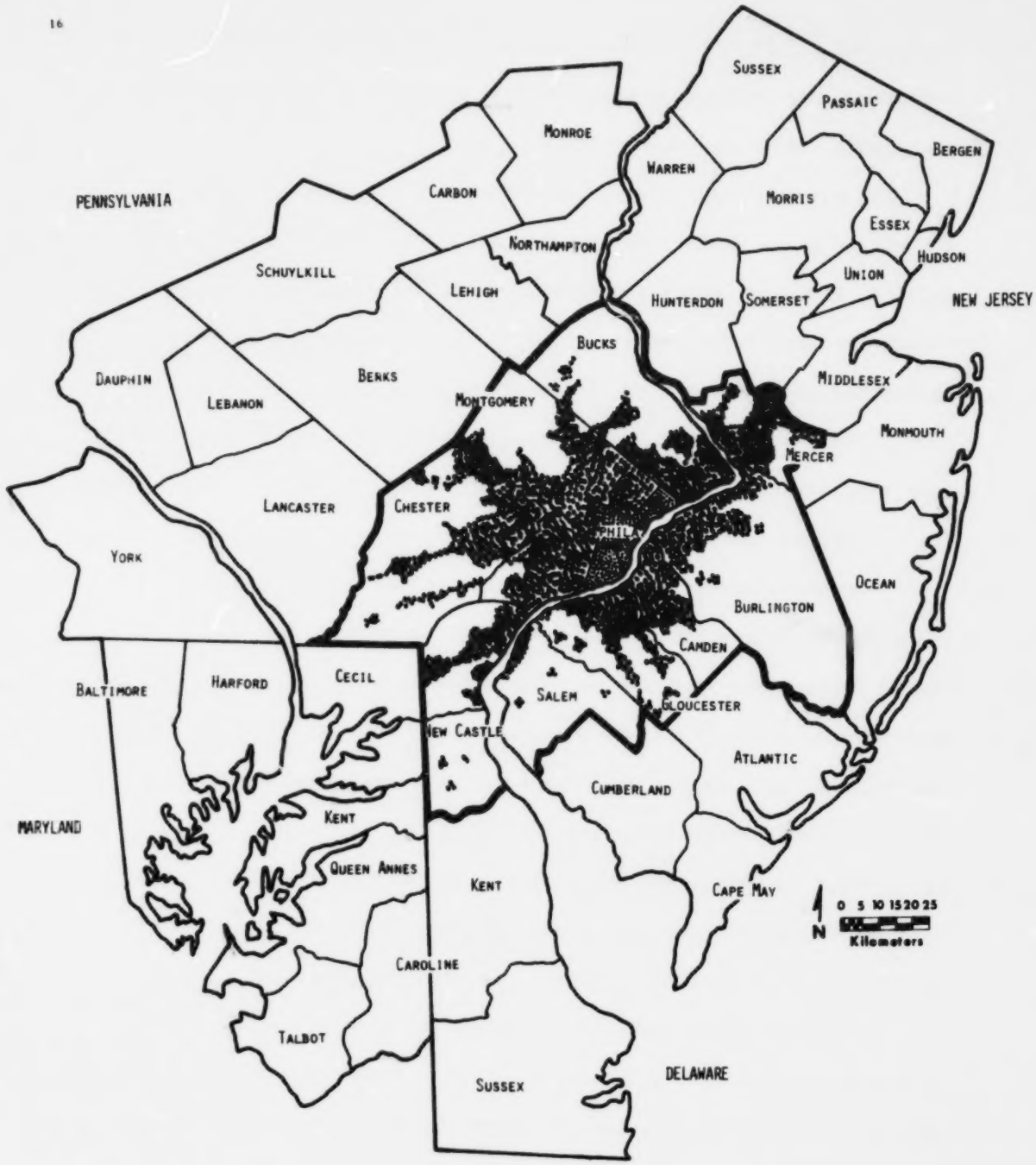


FIGURE 4. DEVELOPED LAND PATTERN

general characteristics of land use patterns). Available projections indicate that land use patterns will remain approximately the same for the foreseeable future. As can be clearly seen, urban centers lie near the center of the eleven county area, following the Delaware River.

Many of the counties surrounding the eleven county area contain urban-industrial complexes and should be considered for inclusion in a region. It might be helpful to analyze these counties, briefly, in conjunction with the Philadelphia urban area.

In New Jersey, the Counties of Monmouth, Middlesex, and Somerset lie in the area recently proposed by this Administration as the New Jersey-New York-Connecticut Interstate Air Quality Control Region. Other New Jersey counties bordering the eleven county area do not contain major urban or industrial concentrations which could serve as either sources or receptors of air pollution.

In Delaware, New Castle County contains the major urban and industrial centers in the State. Since the vast majority of these urban-industrial concentrations are in the northernmost portion of the county, it seems likely that this county will remain the major center of that State's air pollution problem in the years to come.

In Pennsylvania, Lehigh and Northampton Counties form a part of the Allentown-Bethlehem-Easton S.M.S.A. and probably constitute a separate problem though there is an exchange of air pollution across the proposed boundary under certain meteorological conditions. As these counties are not presently coordinated with the eleven counties for air pollution or other administrative purposes, however, they cannot really be considered a cohesive component of any region defined

for that area. The other two Pennsylvania counties bordering the eleven county area do not contain enough urban or industrial concentrations and are not so closely tied to the eleven counties to necessitate their inclusion in an air quality control region at this time.

Cecil County, Maryland, provides the most ambiguous choice of all jurisdictions considered for the Region. This county has recently been added to the Wilmington S.M.S.A. and is beginning to coordinate its planning functions with the planning departments of New Castle County, Delaware, and Salem County, New Jersey. At the present time, it has not developed any formal working relationships with the eleven counties of RCEO. While census figures and estimates show it to be one of the most rapidly growing counties bordering the area, its growth is not concentrated in any manner which would encourage its inclusion in the Region. A further important consideration mitigating against its inclusion in the Region at this time is that the addition of a fourth State, even more than the addition of a twelfth county, to a regional program in which they have not participated in the past, would be quite likely to make any control program unnecessarily cumbersome.

## SUMMARY

The eleven county area which is coextensive with the Regional Conference of Elected Officials and the currently operating interstate cooperative effort at air pollution control constitutes a cohesive combination of urban-industrial complexes highly functional as an air pollution control unit. The existence of such a large number of existing working relationships augurs well for the success of any additional efforts at air pollution control.

Cecil County, Maryland should continue to be viewed as a potential member of the Regional air pollution control effort, but its inclusion is not considered necessary at this time.

## EVALUATION OF ENGINEERING FACTORS

### EMISSION INVENTORY

A quantitative evaluation of air pollution emissions provides the basic framework for air conservation activities. Accordingly, a presentation of the emissions inventory results serves as a logical starting point in the engineering evaluation. The inventory reveals areas that are habitually the emitters of air pollution in varying degrees. In addition, the emissions inventory data is utilized by the diffusion model to systematically predict the spatial and temporal distribution of the pollution emitted into the atmosphere.

The emissions inventory was conducted as part of the Delaware Valley Regional Air Quality Program. It was compiled by the Abatement Program of the National Air Pollution Control Administration, and was conducted over an eleven county area*. The pollutant emissions were calculated on the basis of 1967 data. Within the geographic boundaries of the emission inventory lie the bulk of the population and urbanization associated with metropolitan Philadelphia. The eleven counties also contain the majority of area, point, mobile and stationary sources in the area. In the maps that follow, a heavy line is used to distinguish these eleven counties from the outlying areas.

Five major pollutants were considered in the inventory. These include sulfur oxides, carbon monoxide, total particulates, hydro-

*This area includes the following counties: New Castle County, Delaware; Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties in Pennsylvania; Burlington, Camden, Gloucester, Mercer, and Salem Counties in New Jersey.

carbons and nitrogen dioxide. For the purposes of this report, however, only sulfur oxides*, carbon monoxide and total particulates are considered. These pollutants best represent the spectrum of air pollution sources. Sulfur dioxide levels characterize fuel burning activities, especially at point sources (power plant and other major coal burning plants). Carbon monoxide levels provide the best indication of the impact of motor vehicle emissions in an area. A study of particulate pollution provides a good indication of the effects of all pollutant sources when taken together since all source types contribute significantly to its presence.

Table I summarizes the mean day emissions based on the annual season for the eleven county area. The table also indicates the per cent of the total pollution emitted by each county. Philadelphia, Delaware, and New Castle Counties are the jurisdictions contributing the majority of the pollution emitted.

Figures 5, 6, and 7 are emission density maps for sulfur dioxide, carbon monoxide, and total particulates. These have been constructed for each pollutant according to the season** of greatest emissions. These maps represent the emission densities in relation to the study area by indicating their spatial distribution. A grid system*** over which the density values are distributed provides a more accurate

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*Sulfur dioxide constitutes the majority of sulfur oxide pollution. In this evaluation, sulfur oxide emissions are assumed to be composed entirely of sulfur dioxide. Therefore, diffusion model estimates of $SO_2$ concentrations based on sulfur oxide emissions will not be significantly in error.

**The winter season includes the months of December, January, and February. The summer season includes the months of June, July, and August.

***See Figure A-1, Page 44.

TABLE I. MEAN DAY EMISSIONS* AND PER CENT CONTRIBUTION BY COUNTY

| POLLUTANT / COUNTY | Sulfur Dioxide Tons/day | Percent Total | Carbon Monoxide Tons/day | Percent Total | Total Particulates Tons/day | Percent Total |
|---|---|---|---|---|---|---|
| Delaware | | | | | | |
| New Castle County | 429 | 13.4 | 724 | 9.8 | 54 | 8.5 |
| Pennsylvania | | | | | | |
| Bucks County | 93 | 2.9 | 371 | 5.0 | 36 | 5.7 |
| Chester County | 180 | 5.6 | 292 | 4.0 | 39 | 6.2 |
| Delaware County | 471 | 14.7 | 1129 | 15.3 | 71 | 11.2 |
| Montgomery County | 219 | 6.8 | 806 | 10.9 | 78 | 12.3 |
| Philadelphia County | 1025 | 31.9 | 2280 | 30.9 | 225 | 35.4 |
| Pennsylvania Sub-Total | 1988 | 62.0 | 4878 | 66.0 | 449 | 70.8 |
| New Jersey | | | | | | |
| Burlington County | 104 | 3.2 | 318 | 4.3 | 20 | 3.2 |
| Camden County | 134 | 4.2 | 610 | 8.2 | 35 | 5.4 |
| Gloucester County | 169 | 5.3 | 381 | 5.2 | 22 | 3.5 |
| Mercer County | 224 | 7.0 | 394 | 5.3 | 29 | 4.5 |
| Salem County | 160 | 5.0 | 81 | 1.1 | 26 | 4.1 |
| New Jersey Sub-Total | 791 | 24.6 | 1784 | 24.2 | 132 | 20.7 |
| GRAND TOTAL | 3208 | 100.0 | 7386 | 100.0 | 635 | 100.0 |

*Emissions Based on Annual Average Values

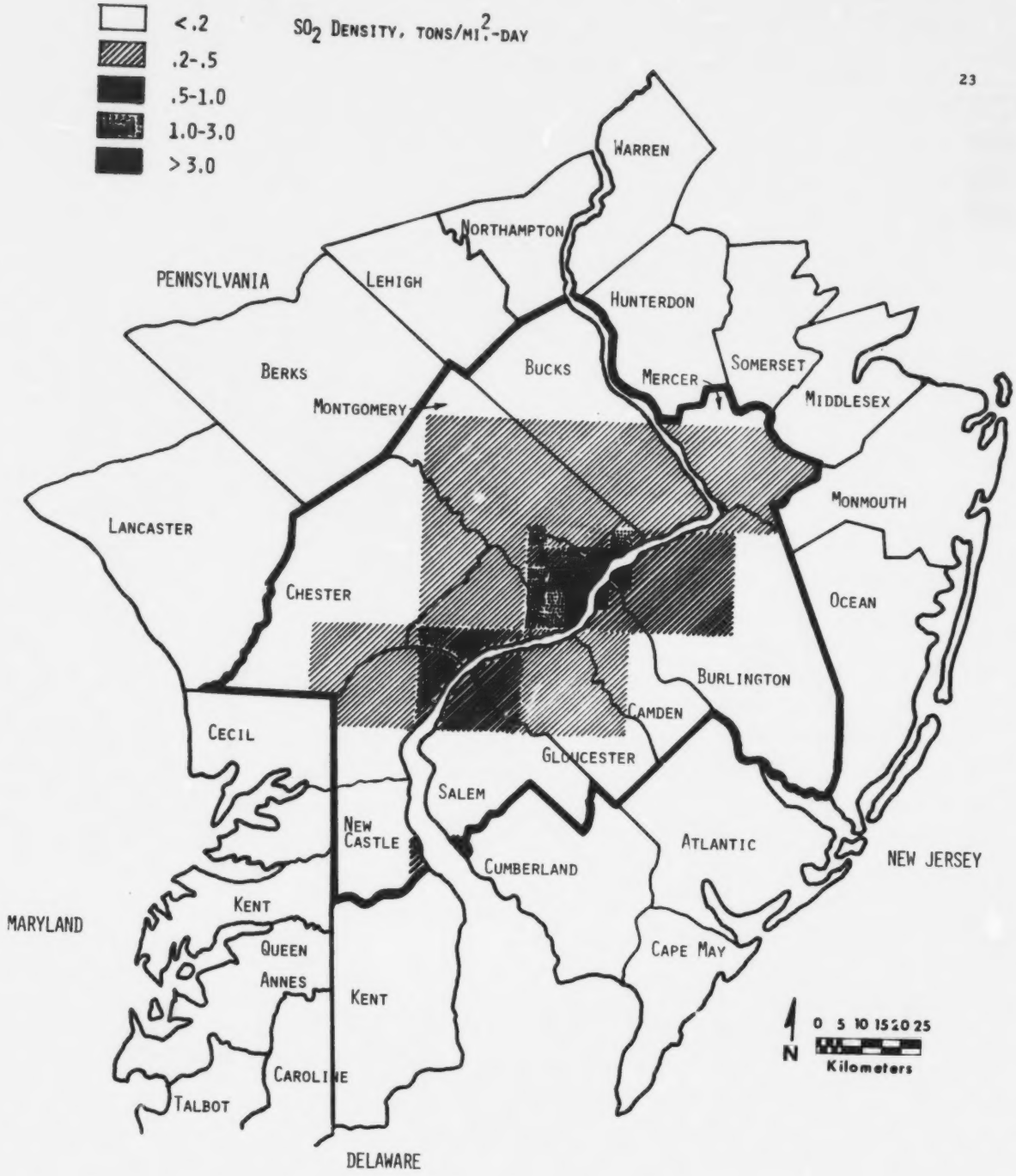


FIGURE 5. $SO_2$ EMISSION DENSITIES BASED ON WINTER AVERAGE VALUES.

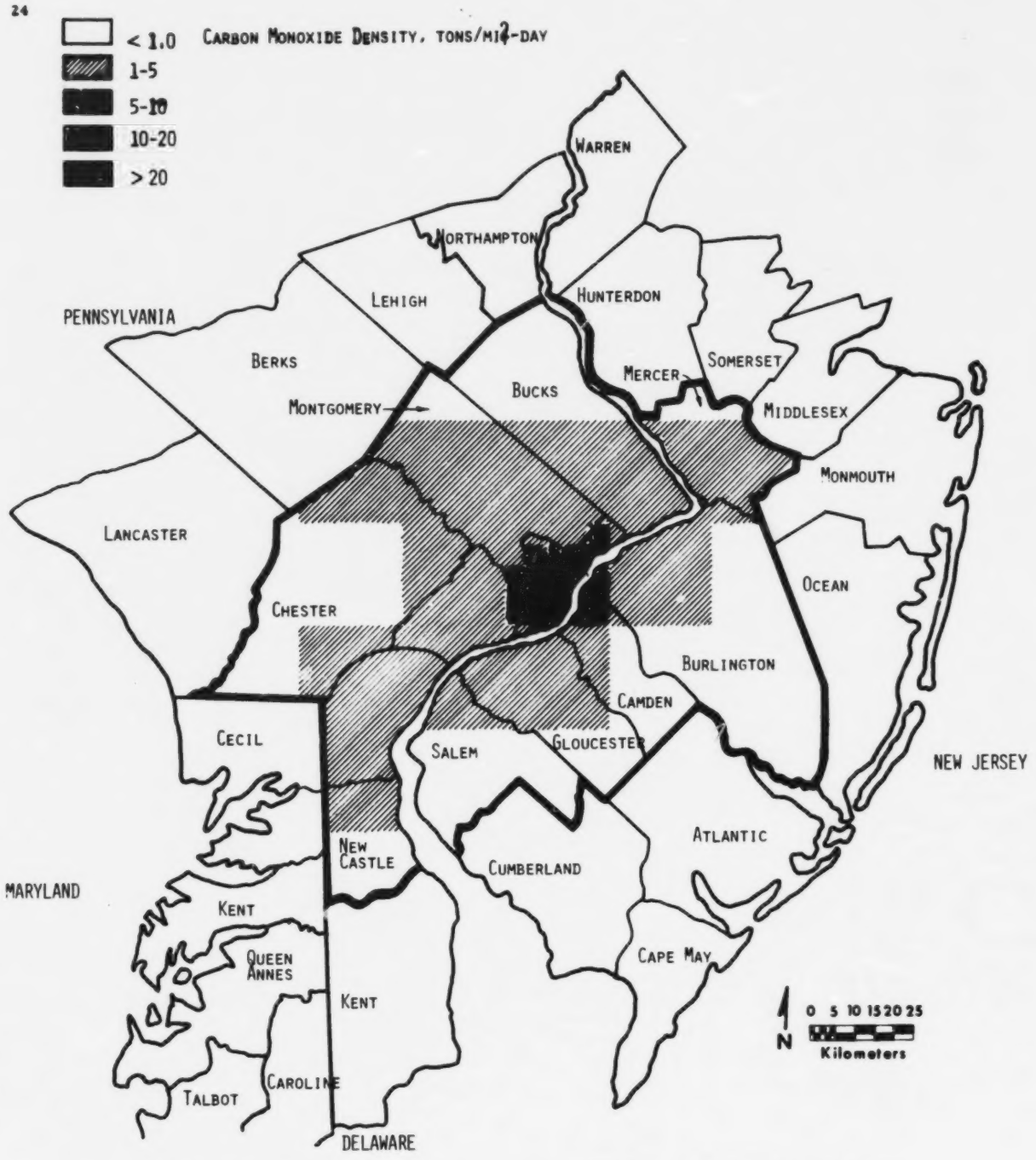


FIGURE 6. CARBON MONOXIDE EMISSION DENSITITES BASED ON SUMMER AVERAGE VALUES.

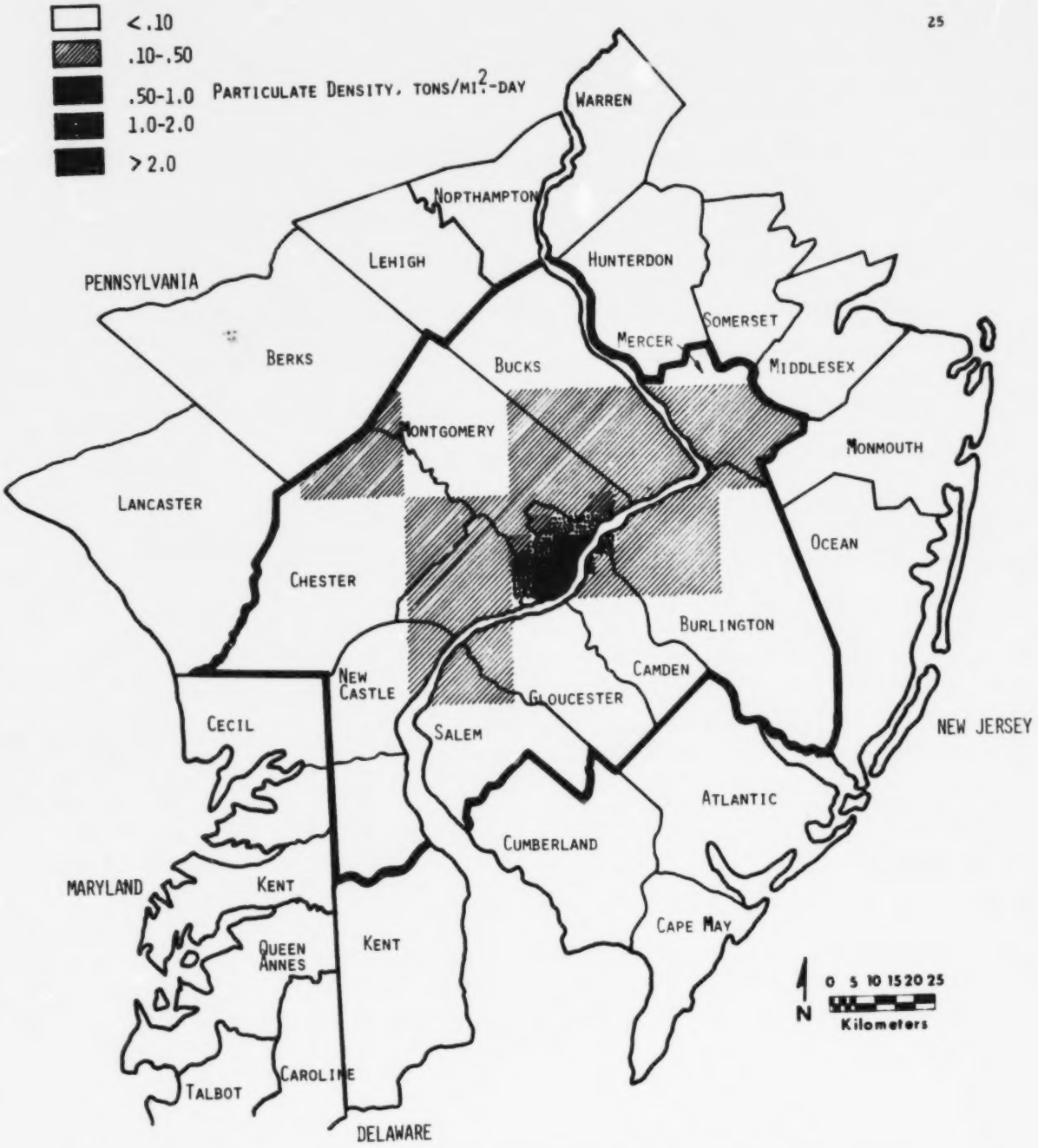


FIGURE 7. TOTAL PARTICULATE EMISSION DENSITIES BASED ON WINTER AVERAGE VALUES.

representation of density magnitudes than does a similar distribution confined by county boundaries.

The areas of greatest pollutant density are those adjacent to the Delaware River or are those areas within or immediately surrounding Philadelphia County. The periphery of the eleven county area shows lower emission densities as evidence of their lack of urbanization.

Figure 8 shows the location and relative size of the major air pollution point sources in the study area. Once again, the majority of the emitters are located along the river, while a few are located at the outskirts of the region.

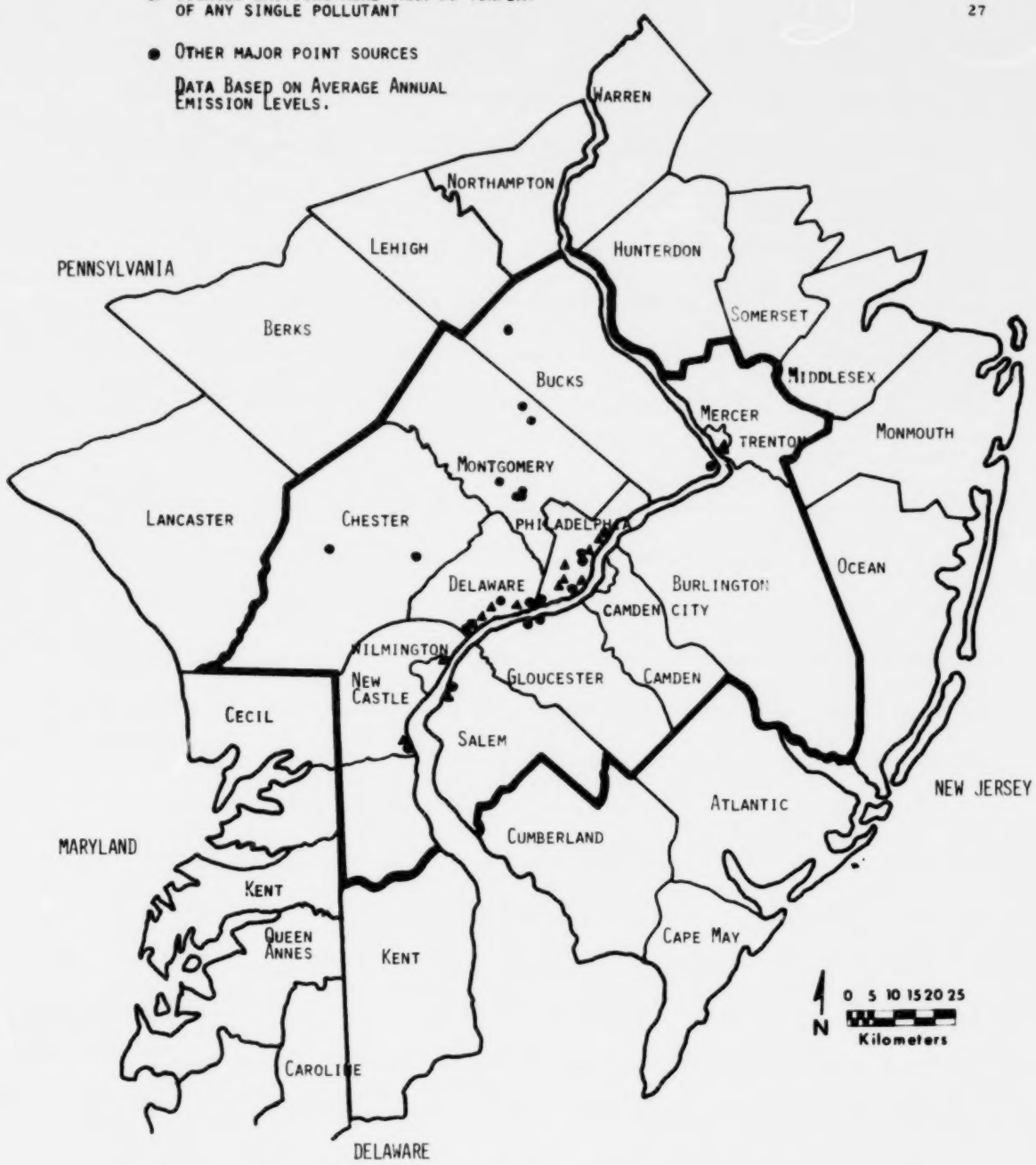


FIGURE 8. LOCATION OF MAJOR POINT SOURCES.

## DIFFUSION MODEL RESULTS

The geographical distribution of pollutant emissions (as Figures 5, 6, and 7 show) provides a good indication of the core area of an air quality control region. Figures showing the location of pollutant emissions permit the identification of the areas that have fostered existing air pollution problems. However, a region that includes not only the areas emitting pollution, but also the areas that are adversely affected by this pollution, cannot be rationally extrapolated from the emissions data alone.

Consideration of air quality data along with emissions data helps to decide the location of an air quality control region's boundaries. In most cases though, air sampling networks do not encompass a large enough area, nor have they been in operation over a sufficient length of time, that they may be considered reliable and irrefutable guides to the establishing of regional boundaries.

A meteorological diffusion model, based on the mathematical treatment of emissions inventory and meteorological data, has been devised. Its results attempt to complement available measurements of air quality. While inherent limitations in the model are recognized, its results can be appropriately modified and interpreted to provide reasonable spatial distributions of long term (seasonal and annual) average pollutant concentrations. The reliance upon existing jurisdictional arrangements (counties) in arriving at the boundaries of a region provides a certain geographical latitude for the diffusion model results. Keeping this in mind, it is improbable that the jurisdictional extent of a region will be significantly altered by minor diffusion model misestimations.

Following is a presentation of the results of the diffusion model as applied to the Pennsylvania-New Jersey-Delaware interstate area. Appendix B explains in detail the methodology and assumptions made in arriving at these results.

Sulfur Dioxide

A known phenomenon associated with the gaseous pollutant sulfur dioxide is its ability to react either photochemically or catalytically with other substances in the atmosphere to form $SO_3$, sulfuric acid, and acid salts. This is commonly referred to as the "decay" of $SO_2$ with time.

Figures B-2 and B-3, located in Appendix B show the diffusion model results for $SO_2$ based on assumed 6 hour and 12 hour half-lives. These are based on meteorological and emissions input data for the annual season.

Figure 9 shows adjusted* annual average concentration contours for an assumed 3 hour half-life for $SO_2$. The assumption of a 3 hour half-life had resulted in concentrations closest in value to measured $SO_2$ levels.

The adjusted contours in Figure 9 were drawn for concentrations of .01 ppm of $SO_2$ or greater. The .01 ppm isopleth is used here as a guide to the minimum size of the region because of its proximity to background levels. Furthermore, an $SO_2$ concentration of .01 ppm is implicated as the threshold (on an annual average basis) of human health effects.

*See discussion in Appendix B, page 55.

FIGURE 9. THEORETICAL $SO_2$ CONCENTRATIONS IN PPM: ANNUAL AVERAGE (ASSUMED 3 HOUR HALF-LIFE WITH VALUES ADJUSTED TO CONFORM TO MEASURED CONCENTRATIONS).

Consequently, the following counties are seen to be significantly affected by sulfur dioxide pollution and should be considered for inclusion as part of the proposed Region: in the State of Delaware -- New Castle County; in the State of New Jersey -- Salem, Gloucester, Camden, Burlington, and Mercer Counties; in the State of Pennsylvania -- Chester, Delaware, Philadelphia, Montgomery, and Bucks Counties.

Carbon Monoxide

The areal extent of the proposed Region, using carbon monoxide concentrations as a guide, is determined on the basis of diffusion model output for the summer season. There are several reasons for this. First, the results of the emission inventory show that carbon monoxide emissions were greatest during the summer season; accordingly, the greatest areas affected by any given CO concentration contour occur during the summer season. The unmodified diffusion model results for the various seasons show this clearly (see Figures B-4, B-5, and B-6). Second, the estimated CO concentrations for the summer season are closest in value to measured air quality levels.

Figure 10 shows the adjusted CO isopleths* for the summer season. The outermost isopleth represents a concentration of 1 ppm. This concentration is assumed to be close to the background level in most highly urbanized areas. One ppm is not a conservative value and therefore includes within its bounds areas affected greatest by the sources within the scope of the emission inventory.

*See Appendix B, page 56, for a discussion of how this was accomplished.

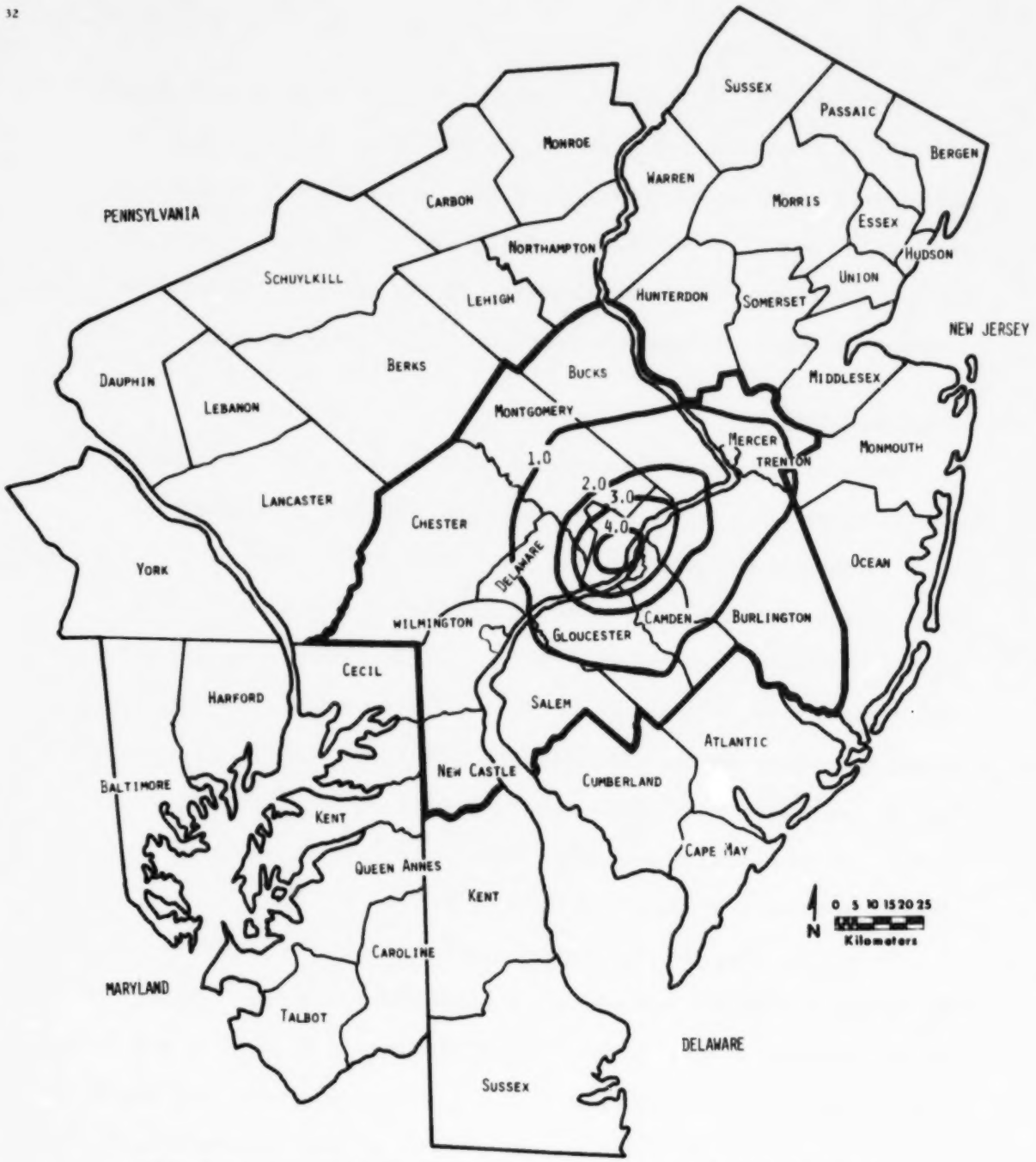


FIGURE 10. THEORETICAL CO CONCENTRATIONS IN PPM: SUMMER AVERAGE (VALUES ADJUSTED TO CONFORM TO MEASURED CONCENTRATIONS).

The 1 ppm concentration contour for carbon monoxide encloses a significant portion of the following counties: in the State of Pennsylvania -- Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties; in the State of New Jersey -- Burlington, Camden, Gloucester, and Mercer Counties. As a result, these counties should be considered for inclusion in the proposed Region.

Suspended Particulates

In order to study the effects of suspended particulates, the diffusion model results for the annual season were used. The theoretical values were adjusted to conform to available air quality data. The annual season was chosen because the greatest areas were enclosed by any given concentration contour and also because more reliable air quality data with which to compare the model results was available for the annual season.

Figure 11 shows the adjusted* theoretical concentrations of suspended particulates. The contours are drawn for concentrations of 40$\mu g/m^3$ or greater. A value of 42$\mu g/m^3$** was assumed as a background level for suspended particulates in the area. The higher concentration levels shown in Figure 11 are the effects of the major air pollution sources within the region.

*See Appendix B, page 62, for a more detailed discussion.

**An average concentration of suspended particulates for non-urban areas in several States whose territory will comprise part of the Region or are nearby States. Values are taken from Air Pollution Measurements of the National Air Sampling Network, Analysis of Suspended Particulates, 1963. U.S. DHEW, Division of Air Pollution, Cincinnati, Ohio, 1965.

FIGURE 11. THEORETICAL PARTICULATE CONCENTRATIONS IN $\mu g/m^3$; ANNUAL AVERAGE (VALUES ADJUSTED TO CONFORM TO MEASURED CONCENTRATIONS).

The inclusion of the following counties is warranted since they are significantly affected by above-background levels of suspended particulate pollution: in the State of Pennsylvania -- Bucks, Delaware, Montgomery, and Philadelphia Counties; in the State of New Jersey -- Burlington, Camden, and Gloucester Counties.

These counties are recommended for inclusion in the proposed Region on the premise that while these jurisdictions may be only partially affected by adverse pollution levels in terms of area, it is necessary to include the entire county in an air quality control region..

Interstate Air Pollution Effects

The use of the diffusion model provides the opportunity to evaluate the impact of selected source-area emissions on air quality in the surrounding areas.

By proper restriction of emissions input data in the diffusion model to sources located only within the State, the impact on the air quality in its own and adjoining State environments can be evaluated. Figures 12, 13, and 14 show the distribution of $SO_2$, assuming no decay, from Pennsylvania, New Jersey, and Delaware sources respectively. These figures show relative concentrations of $SO_2$ and give an indication of the extent of interstate transport of air pollution.

It is evident that considerable air pollution in Wilmington, Delaware, is emitted outside of Delaware while Delaware sources do not measureably contribute to the pollution in Philadelphia or Trenton. Considerable air pollution in Wilmington is also seen to emanate in New Jersey. Salem County, New Jersey, across the Delaware River,

FIGURE 12. THEORETICAL $SO_2$ CONCENTRATIONS IN PPM: ANNUAL AVERAGE (NO DECAY). PENNSYLVANIA SOURCES ONLY.

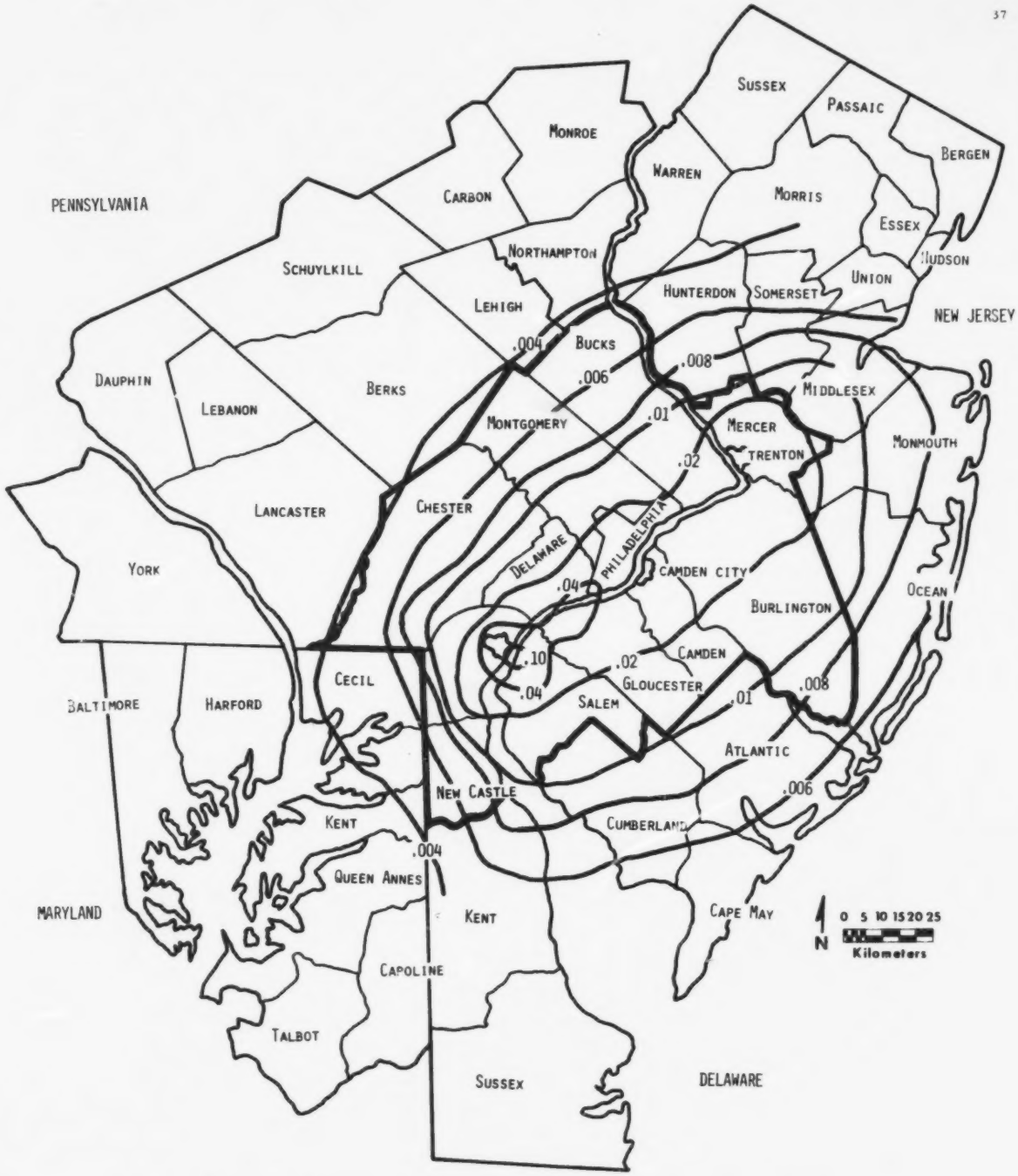


FIGURE 13. THEORETICAL $SO_2$ CONCENTRATIONS IN FPM: ANNUAL AVERAGE (NO DECAY). NEW JERSEY SOURCES ONLY.

FIGURE 14. THEORETICAL $SO_2$ CONCENTRATION IN PPM; ANNUAL AVERAGE (NO DECAY). DELAWARE SOURCES ONLY.

harbors an industrial area consisting of many air pollutant sources. A logical conclusion is that the bulk of the air pollution in Wilmington is attributed to Salem County, New Jersey. These facts are sufficient justification for inclusion of both Salem County, New Jersey, and New Castle County, Delaware, as constituents of the proposed Region.

These figures also show exchange of air pollution between the States of Pennsylvania and New Jersey. This is reason enough to propose an interstate region including areas in the States of New Jersey and Pennsylvania.

## SUMMARY

The major pollutant emissions in the metropolitan Philadelphia interstate area occur along a relatively narrow corridor of land. The corridor stretches from Wilmington northeastward through Philadelphia, Camden, and Trenton. If the location of pollution sources was the only criteria used to determine the boundaries of a region, the Philadelphia Region would include all of Philadelphia and portions of Delaware, Montgomery, and Bucks Counties in Pennsylvania; portions of Mercer, Burlington, Camden, Gloucester, and Salem Counties in New Jersey; and the northernmost part of New Castle County, Delaware.

When the results of the diffusion model calculations are used as a guide in expanding the Region to include people and property affected by emissions, the Region boundaries are extended further into the ten counties listed above and into the eastern portions of Chester County, Pennsylvania.

## APPENDIX A. EMISSION INVENTORY METHODOLOGY

The Abatement Program of the National Air Pollution Control Administration recently completed a preliminary emission inventory as part of the Delaware Valley Regional Air Quality Project. It is an evaluation of the quantities of the five major pollutants (sulfur dioxide, carbon monoxide, particulates, hydrocarbons, and nitrogen dioxide) emitted during the year 1967. The method used, with some modification, was the Public Health Service rapid survey technique for estimating pollutant emissions.[1] Following is a summary of the survey scope and methodology for the various source categories.

Emissions from area fuel combustion in stationary sources were calculated on the basis of consumed quantities of anthracite coal, bituminous coal, distillate oil, residual oil, and natural gas. Industrial coal burning was assumed to be 30% controlled, while the combustion of all other fuels was considered to occur without control equipment.

The inventorying of transportation emissions involved consideration of oil-fired vessels, trains, aircraft, and motor vehicles as source categories. In calculating emissions from vessels, it was assumed that all vessels were oil-fired and that fuel consumption was directly related to ton-miles of shipping. The pollutant quantities were allocated to specific grid emission zones on the basis of ton-miles at each port in the study area. Railroad fuel comsumption was allocated to counties on the basis of statewide figures and the ratio of county to State

transportation employees. Aircraft emissions were computed from data supplied by the airports in the study area. This data included the number of annual operations at each airport and their distribution by the type and size of the aircraft involved. Motor vehicle emissions were computed for both gasoline and diesel-oil burning vehicles. Fuel consumption figures were first apportioned to each county from State service station sales, and then apportioned to grid emission zones on the basis of land usage (i.e., residential, commerical, and industrial areas). Philadelphia vehicular emissions were distributed into the appropriate grid zones on the basis of vehicle miles traveled within the respective zones.

Emissions from solid waste disposal were based on data collected from the Office of Solid Wastes of the U. S. Public Health Service. Data obtained directly from the incinerators located in the study area was also used. The total quantity of refuse generated was based on a value of five pounds/capita-day and was apportioned to either municipal incineration, burning dumps, landfill operations or domestic and commercial-industrial on-site incineration.

It is difficult to make an accurate estimate of process emissions in a short term survey. As a result, process emission figures were taken from the results of the emissions inventory conducted by the Environmental Engineering and Science Program at the Drexel Institute of Technology.[2] This survey was conducted over an eleven county area coextensive with the National Air Pollution Control Administration's emissions study.

Emissions from power plants were computed on the basis of fuel use, boiler, collection efficiency and control equipment data submitted by these companies themselves.

Public Health Service emission factors[3] were used in making estimations of air pollutant emissions from the various sources. They represent statistical averages of the rate at which pollutants are emitted from the burning or processing of a given quantity of material.

The grid system used in the emissions inventory is shown in Figure A-1; it is superimposed over a map of the study area involved in the inventory. The pollutant emissions normally allocated to the various counties involved in the survey were allocated to the numbered grid zones. This served to provide a more definitive geographic breakdown of emissions and provided a means by which the diffusion model analysis could be effectuated.

Figures 5, 6, and 7, the emission density maps, are based on this grid system. The large grid block over Philadelphis was subdivided into 25 smaller blocks for the sake of accuracy in an area where the magnitude of pollution emission is the greatest. Table A-1 lists the emission density values by grid zone for the various pollutants. These values are for area sources only and are exclusive of point source contributions. The emissions of these air pollution point sources are included in the diffusion model study, however.

Table A-1 gives emission densities in terms of mean-day values over annual, summer, and winter seasons for each of the three pollutants used in the diffusion model study. This was done in order that the diffusion

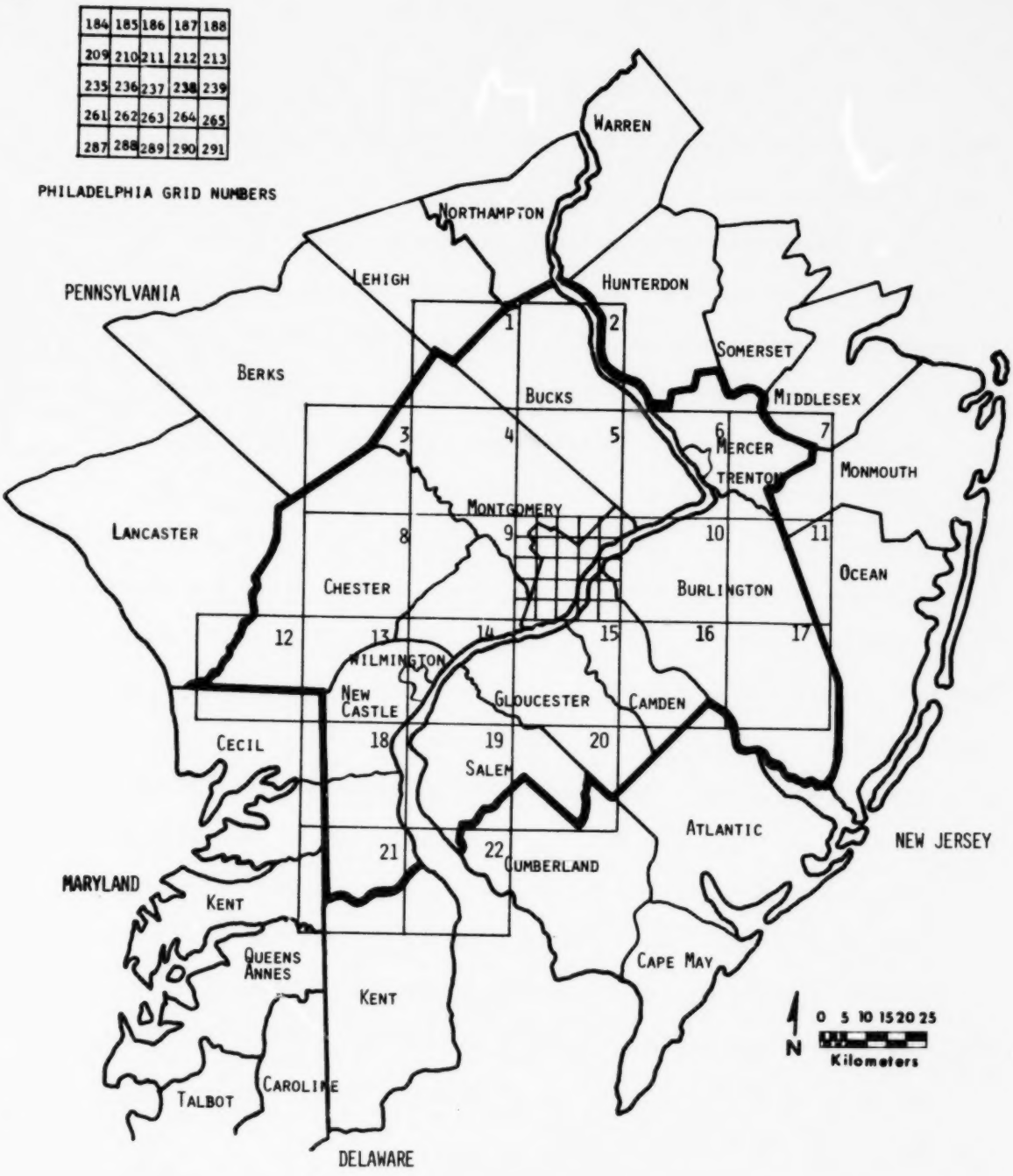


FIGURE A-1. EMISSION INVENTORY GRID SYSTEM

TABLE A-1. DAILY EMISSION DENSITIES FOR AVERAGE ANNUAL, SUMMER, AND WINTER DAYS
(tons/mi$^2$-day)

| GRID ZONE | ZONE AREA (mi.$^2$) | SULFUR DIOXIDE | | | CARBON MONOXIDE | | | PARTICULATES | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Annual | Summer | Winter | Annual | Summer | Winter | Annual | Summer | Winter |
| 1 | 147 | .091 | .074 | .12 | .441 | .468 | .421 | .033 | .023 | .042 |
| 2 | 206 | .028 | .019 | .04 | .030 | .030 | .030 | .010 | .007 | .013 |
| 3 | 138 | .028 | .024 | .034 | .97 | 1.03 | .96 | .088 | .08 | .10 |
| 4 | 241 | .27 | .23 | .33 | 1.06 | 1.15 | 1.01 | .85 | .075 | .095 |
| 5 | 241 | .27 | .21 | .35 | 1.25 | 1.31 | 1.19 | .92 | .075 | .114 |
| 6 | 241 | .36 | .28 | .46 | 1.75 | 1.89 | 1.66 | .12 | .11 | .15 |
| 7 | 127 | .21 | .15 | .29 | 1.46 | 1.57 | 1.37 | .10 | .088 | .11 |
| 8 | 241 | .12 | .087 | .15 | .47 | .50 | .45 | .038 | .033 | .046 |
| 9 | 241 | .33 | .24 | .44 | 2.39 | 2.49 | 2.32 | .14 | .11 | .18 |
| 10 | 241 | .31 | .17 | .51 | 1.19 | 1.26 | 1.13 | .08 | .063 | .10 |
| 11 | 153 | .03 | .015 | .05 | .20 | .21 | .18 | .012 | .01 | .014 |
| 12 | 112 | .009 | .008 | .02 | .090 | .096 | .086 | .004 | .002 | .006 |
| 13 | 225 | .18 | .12 | .26 | 1.45 | 1.55 | 1.37 | .048 | .038 | .061 |
| 14 | 216 | .57 | .53 | .94 | 4.04 | 4.20 | 3.90 | .27 | .16 | .20 |
| 15 | 233 | .26 | .18 | .37 | 1.93 | 1.85 | 2.02 | .057 | .043 | .075 |
| 16 | 230 | .12 | .085 | .17 | .66 | .71 | .63 | .036 | .031 | .043 |
| 17 | 231 | .007 | .002 | .01 | .026 | .028 | .024 | .001 | .001 | .002 |
| 18 | 167 | .17 | .16 | .18 | .94 | 1.00 | .89 | .046 | .040 | .047 |
| 19 | 184 | .084 | .078 | .09 | .16 | .18 | .15 | .025 | .024 | .026 |
| 20 | 161 | .071 | .015 | .09 | .47 | .49 | .45 | .020 | .018 | .022 |
| 21 | 110 | .006 | .002 | .010 | .080 | .085 | .075 | .002 | .002 | .003 |
| 22 | 16.4 | .72 | .79 | .66 | .005 | .005 | .004 | .051 | .055 | .048 |

TABLE A-1. DAILY EMISSION DENSITIES FOR AVERAGE ANNUAL, SUMMER, AND WINTER DAYS
(tons/mi$^2$-day)

| GRID ZONE | ZONE AREA (mi$^2$) | SULFUR DIOXIDE | | | CARBON MONOXIDE | | | PARTICULATES | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Annual | Summer | Winter | Annual | Summer | Winter | Annual | Summer | Winter |
| 184 | 9.64 | 1.21 | 1.10 | 1.35 | 3.23 | 3.43 | 3.06 | .35 | .33 | .38 |
| 185 | 9.64 | .42 | .034 | .91 | 3.87 | 3.85 | 3.76 | .16 | .066 | .28 |
| 186 | 9.64 | .38 | .045 | .79 | 3.82 | 3.86 | 3.84 | .22 | .083 | .40 |
| 187 | 9.64 | .51 | .048 | 1.08 | 4.22 | 4.35 | 4.17 | .22 | .085 | .38 |
| 188 | 9.64 | 2.13 | 1.56 | 2.73 | 10.2 | 10.6 | 9.81 | .73 | .60 | .88 |
| 209 | 9.64 | .60 | .36 | .90 | 2.57 | 2.69 | 2.48 | .28 | .23 | .35 |
| 210 | 9.64 | .77 | .062 | 1.65 | 6.55 | 6.78 | 6.46 | .30 | .092 | .56 |
| 211 | 9.64 | 3.02 | 1.83 | 4.52 | 15.1 | 15.6 | 14.8 | 1.05 | .73 | 1.46 |
| 212 | 9.64 | 3.81 | 2.69 | 5.20 | 17.0 | 17.5 | 16.7 | 1.34 | 1.03 | 1.74 |
| 213 | 9.64 | 3.85 | 2.68 | 5.32 | 13.3 | 13.6 | 13.2 | 1.27 | .98 | 1.64 |
| 235 | 9.64 | 1.28 | .91 | 1.74 | 5.80 | 5.87 | 5.78 | .49 | .37 | .66 |
| 236 | 9.64 | 3.46 | 2.72 | 4.39 | 19.7 | 20.7 | 18.9 | 1.28 | 1.10 | 1.51 |
| 237 | 9.64 | 4.76 | 3.60 | 6.21 | 25.1 | 26.1 | 24.2 | 1.73 | 1.42 | 2.13 |
| 238 | 9.64 | 5.61 | 3.54 | 7.04 | 19.8 | 20.4 | 19.4 | 2.96 | 2.83 | 3.21 |
| 239 | 9.64 | 4.12 | 3.69 | 4.68 | 11.9 | 12.4 | 11.5 | 1.14 | 1.06 | 1.24 |
| 261 | 9.64 | 1.82 | 1.20 | 2.59 | 10.5 | 10.8 | 10.4 | .61 | .45 | .87 |
| 262 | 9.64 | 1.85 | .77 | 3.78 | 28.5 | 30.1 | 27.2 | 1.82 | 1.55 | 2.19 |
| 263 | 9.64 | 6.14 | 4.91 | 8.70 | 26.2 | 27.6 | 25.1 | 2.90 | 2.56 | 3.40 |
| 264 | 9.64 | 5.54 | 4.90 | 6.45 | 12.9 | 13.6 | 12.3 | 1.08 | .96 | 1.24 |
| 265 | 9.64 | .81 | .46 | 1.25 | 5.04 | 5.41 | 4.74 | .23 | .18 | .29 |
| 287 | 9.64 | 2.12 | 1.69 | 2.66 | 12.9 | 13.2 | 12.7 | .81 | .67 | 1.00 |
| 288 | 9.64 | 1.42 | .95 | 1.99 | 10.6 | 11.2 | 10.2 | 2.55 | 2.43 | 2.72 |
| 289 | 9.64 | 6.04 | 5.67 | 6.88 | 15.0 | 15.5 | 14.6 | 1.87 | 1.75 | 2.03 |
| 290 | 9.64 | .73 | .47 | 1.06 | 5.56 | 5.93 | 5.33 | .23 | .19 | .29 |
| 291 | 9.64 | .62 | .30 | 1.02 | 5.68 | 6.11 | 5.33 | .20 | .15 | .26 |

model could provide concentration distributions for each of the three seasons. The conversion of mean-day emissions based on total annual emissions values to mean-day winter and summer seasonal values was accomplished using appropriate heating-degree-day values for the study area and the portion of fuels used for space heating purposes. Factors were applied to emissions from other sources (e.g., motor vehicles) which would bring the seasonal emission values in line with observed trends for various sources and pollutants.

Tables A-2, A-3 and A-4 summarize the estimates of annual emissions by source classification and by jurisdiction for $SO_2$, CO and total particulates respectively.

TABLE A-2. SULFUR DIOXIDE EMISSIONS BY SOURCE CLASSIFICATION
(tons/year)

| SOURCE CLASSIFICATION / COUNTY | GRAND TOTAL | FUEL COMBUSTION STATIONARY SOURCES | POWER PLANTS | PROCESS EMISSIONS | SOLID WASTE DISPOSAL | MOTOR VEHICLES | OTHER FORMS OF TRANSPORTATION |
|---|---|---|---|---|---|---|---|
| DELAWARE | | | | | | | |
| New Castle County | 156,307 | 27,755 | 100,811 | 21,400 | 19 | 978 | 5,344 |
| PENNSYLVANIA | | | | | | | |
| Bucks County | 33,853 | 12,809 | 280 | 19,050 | 25 | 656 | 1,033 |
| Chester County | 65,597 | 10,423 | 41,268 | 13,310 | 8 | 528 | 60 |
| Delaware County | 171,651 | 20,673 | 83,746 | 63,680 | 320 | 1,021 | 2,211 |
| Montgomery County | 79,596 | 30,093 | 13,386 | 34,450 | 229 | 1,295 | 143 |
| Philadelphia County | 373,090 | 106,713 | 124,621 | 124,485 | 932 | 2,859 | 13,480 |
| Pennsylvania Sub-Total | 723,787 | 180,711 | 263,301 | 254,975 | 1,514 | 6,359 | 16,927 |
| NEW JERSEY | | | | | | | |
| Burlington County | 37,773 | 15,364 | 11,383 | 8,610 | 14 | 545 | 1,857 |
| Camden County | 48,888 | 17,057 | -- | 19,830 | 67 | 926 | 11,008 |
| Gloucester County | 61,507 | 4,857 | 9,905 | 43,490 | 8 | 303 | 2,944 |
| Mercer County | 81,631 | 10,601 | 59,188 | 10,700 | 79 | 667 | 396 |
| Salem County | 58,178 | 5,761 | 37,224 | 8,875 | 2 | 152 | 6,164 |
| New Jersey Sub-Total | 287,977 | 53,640 | 117,700 | 91,505 | 170 | 2,593 | 22,369 |
| GRAND TOTAL | 1,168,098 | 262,106 | 481,812 | 367,880 | 1,703 | 9,930 | 44,640 |

TABLE A-3. CARBON MONOXIDE EMISSIONS BY SOURCE CLASSIFICATION
(tons/year)

| SOURCE CLASSIFICATION / COUNTY | GRAND TOTAL | FUEL COMBUSTION STATIONARY SOURCES | POWER PLANTS | PROCESS EMISSIONS | SOLID WASTE DISPOSAL | MOTOR VEHICLE | OTHER FORMS OF TRANSPORTATION |
|---|---|---|---|---|---|---|---|
| DELAWARE | | | | | | | |
| New Castle County | 263,753 | 1,630 | 341 | 46,710 | 5,222 | 206,108 | 3,742 |
| PENNSYLVANIA | | | | | | | |
| Bucks County | 134,903 | 2,663 | 4 | 8,090 | 4,187 | 119,644 | 315 |
| Chester County | 106,458 | 1,887 | 223 | 6,000 | 2,006 | 96,253 | 89 |
| Delaware County | 410,634 | 4,584 | 411 | 210,345 | 8,693 | 186,281 | 320 |
| Montgomery County | 293,369 | 5,110 | 73 | 35,230 | 15,891 | 234,917 | 2,148 |
| Philadelphia County | 831,942 | 18,445 | 501 | 273,500 | 10,441 | 521,266 | 7,789 |
| Pennsylvania Sub-Total | 1,777,306 | 32,689 | 1,212 | 533,165 | 41,218 | 1,158,361 | 10,661 |
| NEW JERSEY | | | | | | | |
| Burlington County | 115,858 | 659 | 3 | 8,350 | 4,830 | 101,424 | 592 |
| Camden County | 222,076 | 1,073 | -- | 41,495 | 7,247 | 172,076 | 185 |
| Gloucester County | 138,860 | 356 | 48 | 80,380 | 1,770 | 56,244 | 62 |
| Mercer County | 143,288 | 1,014 | 322 | 9,395 | 4,108 | 123,900 | 4,549 |
| Salem County | 29,637 | 168 | 100 | 780 | 755 | 27,781 | 53 |
| New Jersey Sub-Total | 649,719 | 3,270 | 473 | 140,400 | 18,710 | 481,425 | 5,441 |
| GRAND TOTAL | 2,690,778 | 37,589 | 2,026 | 720,275 | 65,150 | 1,845,894 | 19,844 |

TABLE A-4. TOTAL PARTICULATE EMISSIONS BY SOURCE CLASSIFICATION
(tons/year)

| SOURCE CLASSIFICATION / COUNTY | GRAND TOTAL | FUEL COMBUSTION STATIONARY SOURCES | POWER PLANTS | PROCESS EMISSIONS | SOLID WASTE DISPOSAL | MOTOR VEHICLES | OTHER FORMS OF TRANSPORTATION |
|---|---|---|---|---|---|---|---|
| DELAWARE | | | | | | | |
| New Castle County | 19,718 | 3,192 | 7,482 | 6,260 | 695 | 1,547 | 542 |
| PENNSYLVANIA | | | | | | | |
| Bucks County | 10,212 | 3,349 | 340 | 7,570 | 515 | 1,143 | 295 |
| Chester County | 14,312 | 2,441 | 5,292 | 5,220 | 286 | 919 | 164 |
| Delaware County | 25,907 | 5,355 | 3,506 | 12,525 | 2,038 | 1,779 | 704 |
| Montgomery County | 28,527 | 7,148 | 3,507 | 13,050 | 2,167 | 2,263 | 392 |
| Philadelphia County | 81,911 | 24,930 | 9,165 | 36,535 | 3,271 | 4,979 | 3,031 |
| Pennsylvania Sub-Total | 163,879 | 43,223 | 21,810 | 74,900 | 8,277 | 11,083 | 4,586 |
| NEW JERSEY | | | | | | | |
| Burlington County | 7,290 | 1,905 | 509 | 2,870 | 635 | 938 | 433 |
| Camden County | 12,600 | 2,884 | --- | 6,260 | 870 | 1,595 | 991 |
| Gloucester County | 8,069 | 862 | 1,492 | 4,695 | 215 | 521 | 284 |
| Mercer County | 10,407 | 1,832 | 1,545 | 4,960 | 740 | 1,148 | 182 |
| Salem County | 9,481 | 609 | 3,101 | 4,960 | 87 | 226 | 458 |
| New Jersey Sub-Total | 47,847 | 8,092 | 6,647 | 23,745 | 2,547 | 4,468 | 2,348 |
| GRAND TOTAL | 231,444 | 54,507 | 35,939 | 104,905 | 11,519 | 17,098 | 7,476 |

## REFERENCES FOR APPENDIX A

1. Public Health Service. Rapid Survey Technique for Estimating Community Air Pollution Emissions. Publication No. 999-AP-29, Environmental Health Series, U.S.DHEW, Division of Air Pollution, Cincinnati, Ohio, October, 1966.

2. Wohlers, H. C., Jackson, W. H. Air Pollution Emissions in the Delaware Valley. Environmental Engineering and Science Program, Drexel Institute of Technology, RCEO Air Pollution Survey Report, Philadelphia, Pennsylvania, 1968.

3. Public Health Service. Compilation of Air Pollutant Emission Factors. Publication No. 999-AP-42, Environmental Health Series, U.S.DHEW, National Center for Air Pollution Control, Durham, North Carolina

# APPENDIX B. DIFFUSION MODEL DESCRIPTION AND METHODOLOGY

## GENERAL DESCRIPTION

Title I, Section 107 (a) (2) of the Air Quality Act of 1967 (Public Law 90-148, dated November 21, 1967), calls for the designation of air quality control regions based on a number of factors, including "atmospheric areas" interpreted to mean that the bouncaries of air quality control regions should reflect the technical aspects of air pollution (climate, meteorology, topography) and the dispersion of this pollution. Within this guideline, however, the position has been taken that boundaries of a region cannot be seasonally dependant nor should these boundaries be based on an extreme and theoretically plausible set of circumstances leading to an enlarged or diminished region. The diffusion model analysis does distinguish between annual, summer, and winter mean values with regard to variable meteorological and emission parameters. These conditions, however, are not indicative of an extreme set of circumstances such as are mentioned above.

The diffusion model is based on the Gaussian diffusion equation, described by Pasquill[1,2] for long term averages, and modified in recent years[3,4] for application to the multiple-source situations typical of an urban complex. The basic equation assumes that the concentration of a pollutant within a plume has a Gaussian distribution about the plume centerline in the vertical and horizontal direction. The dispersion of this plume is a function of atmospheric stability conditions and the distance from the source. The plume is assumed to move downwind according to the mean wind.

The diffusion model was applied to the three pollutants of concern (CO, $SO_2$, and particulates). Results were derived for the dispersion of these pollutants on the basis of annual, winter, and summer seasons. In order that this could be done, certain fundamental meteorological parameters were evaluated for use in the diffusion equation. Table B-1 shows average mixing depths for various seasons and periods during the day.

TABLE B-1.
Average Mixing Depths For the Philadelphia Area, By Season

| SEASON | Mixing Depths* (meters) | | |
|---|---|---|---|
| | Morning Average | Afternoon Average | Average, Morning and Afternoon |
| Winter | 705 | 935 | 820 |
| Summer | 514 | 1699 | 1106 |
| Annual | 592 | 1360 | 976 |

Figure B-1 typifies wind data in the Philadelphia area** in terms of frequency of occurrence in the respective compass directions for the three seasons of concern. The characteristic prevailing wind directions for each of the seasons exerts a major influence over the seasonal dispersion of pollutants as may be observed in the shapes of the concentration isopleths.

*Computed mixing depths documented by Holzworth[5,6] and recent tabulations furnished the Meteorological Program, NAPCA, by National Weather Records Center, ESSA.

**U.S. Weather Bureau Data.

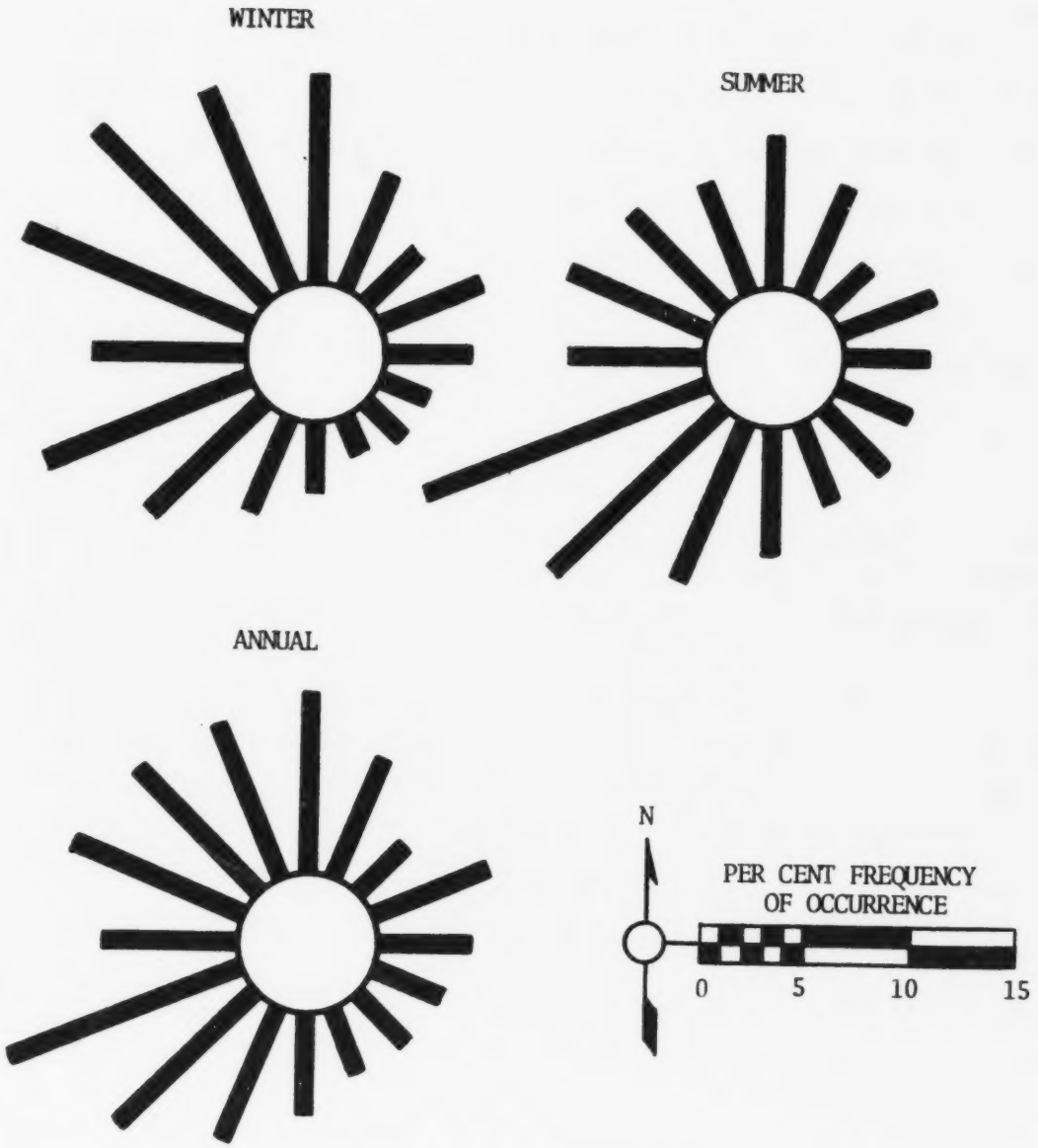


FIGURE B-1. WIND DIRECTION PER CENT FREQUENCY OF OCCURRENCE FOR VARIOUS AVERAGING TIMES.

The diffusion model was used in this study to compute the ground level concentrations of pollutants at 97 points. These points were distributed over 16 compass directions up to 100 kilometers from the assumed center point (the intersection of Vine and Broad Streets, Philadelphia). All pollutant sources were assumed to be at ground level and topographical features were disregarded. This nullification of source and receptor height considerations can be tolerated, to an extent, since the distances between source-receptors points involved are sufficiently great so as to diminish elevations as a variable for the other portions of the area.

SULFUR DIOXIDE

A comparison of mean annual $SO_2$concentrations derived from the diffusion model analysis with measured ambient air quality levels showed that in all cases the model tended to over-estimate the measured concentrations. Calculated values assuming no decay showed the greatest discrepancies. As a result, "decay factors"* were applied to the diffusion model output for mean annual $SO_2$ concentrations assuming 3, 6, and 12 hour half-lives.

The theoretical concentration values for an assumed 3 hour half-life were in closest agreement with measured values. This did not obviate the necessity of further adjustment of the theoretical values. A comparison of these theoretical values with reliable measured values

*Such a factor was not included as a modification of any of the diffusion model equations. Because of this the model output (concentration values) was treated in order that the adjusted pollutant levels could be obtained.

(annual average values) at 7 monitoring stations showed that the measured values averaged 0.27 of the theoretical values at these station (min., 0.17; max., 0.48). Thus 0.27 served as the factor with which the theoretical concentration contours were adjusted.

Figures B-2 and B-3 show theoretical $SO_2$ concentration contours with assumed 6 hour and 12 hour half-lives respectively. The theoretical concentrations have not been adjusted to conform to measured air quality.

CARBON MONOXIDE

Figures B-4, B-5, and B-6 show unadjusted CO isopleths for summer, annual, and winter seasons, respectively.

Summer average CO concentrations measured at 2 air sampling stations in the City of Philadelphia are understimated by the diffusion model concentration (summer averages) at the sampling station's sites. The diffusion model does not reflect the built up nature of the area over which most CO is emitted. Therefore, the model assumes that the CO has more volume to disperse in than is the actual case. Consequently, an average factor of 3.4 was applied to the theoretical concentration values for the summer season in order to align predicted concentration with measured concentrations*.

The isopleths are a good indication of the relative distribution of carbon monoxide pollution over the area of concern. Their shape reflects the influence of the prevailing wind directions, particularly during the summer season (WSW). The areas downwind of the major source are affected by the emissions from these sources while upwind source areas such as

*See Figure 10, page 32. The value of 3.4 as an average factor is compatible with similar factors applied to a study of CO pollution in the Washington, D. C. and New York Metropolitan areas.

FIGURE B-2. THEORETICAL $SO_2$ CONCENTRATIONS IN PPM: ANNUAL AVERAGE (ASSUMED 6 HOUR HALF-LIFE).

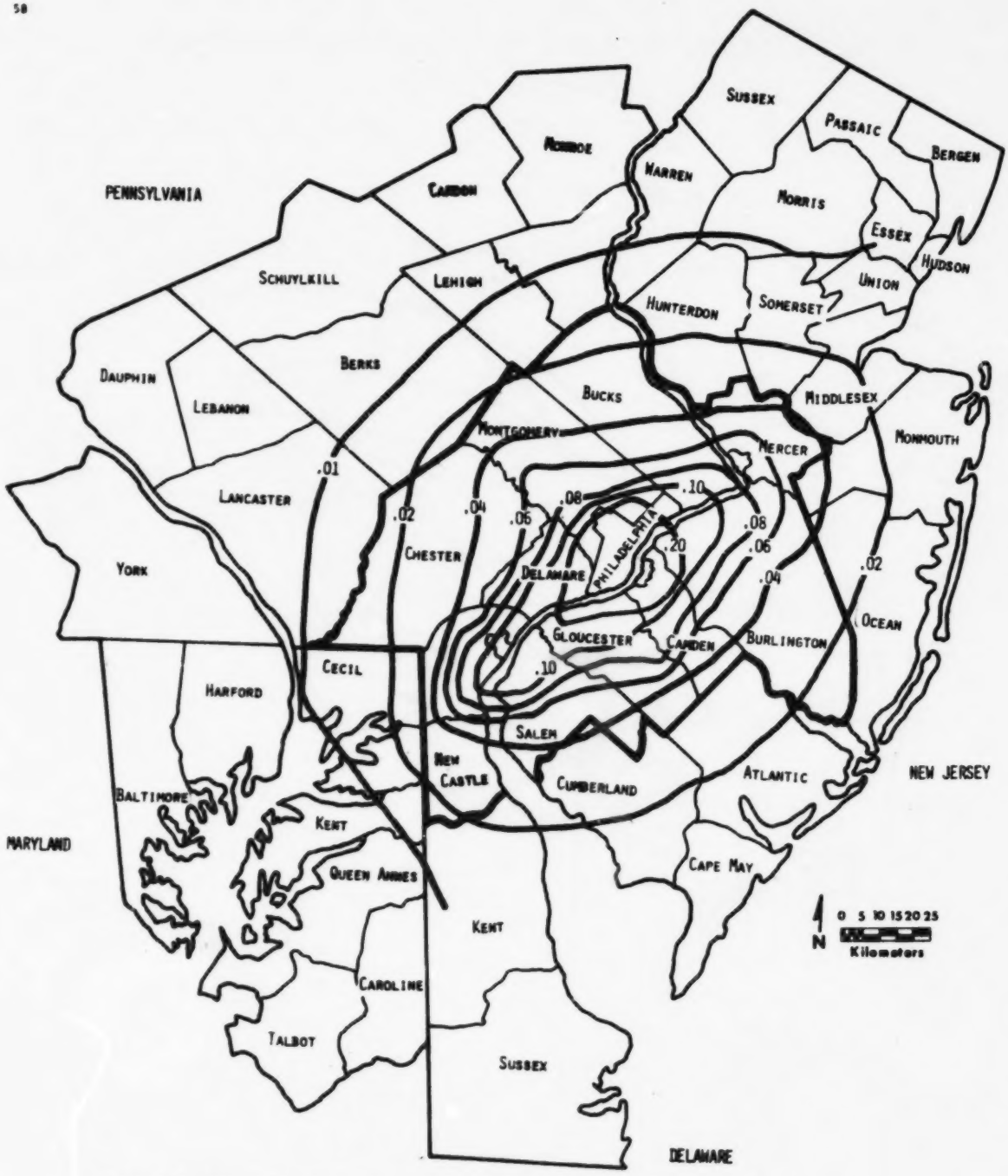


FIGURE B-3. THEORETICAL $SO_2$ CONCENTRATIONS IN PPM: ANNUAL AVERAGE (ASSUMED 12 HOUR HALF-LIFE).

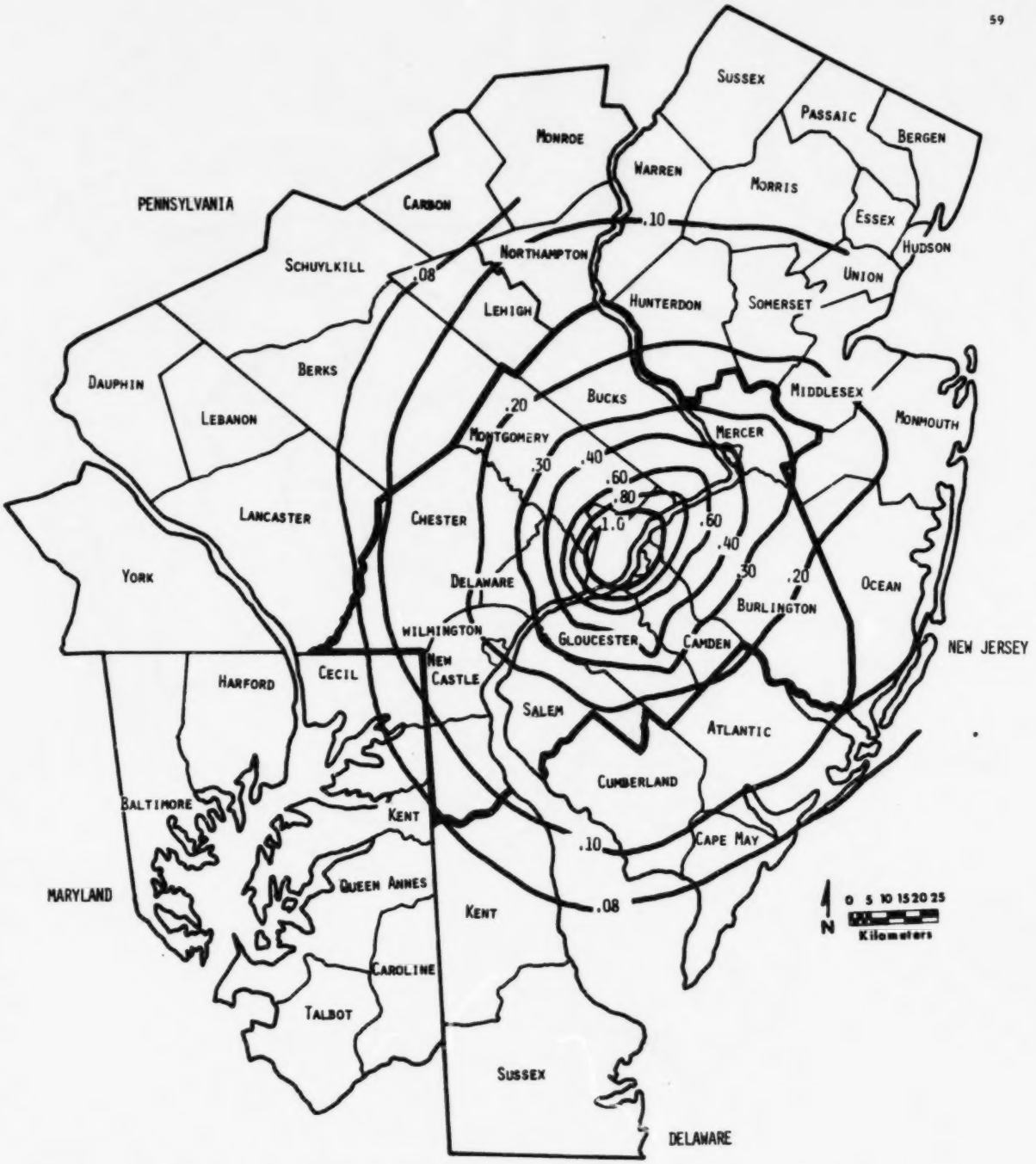


FIGURE B-4. THEORETICAL CO CONCENTRATIONS IN PPM; SUMMER AVERAGE.

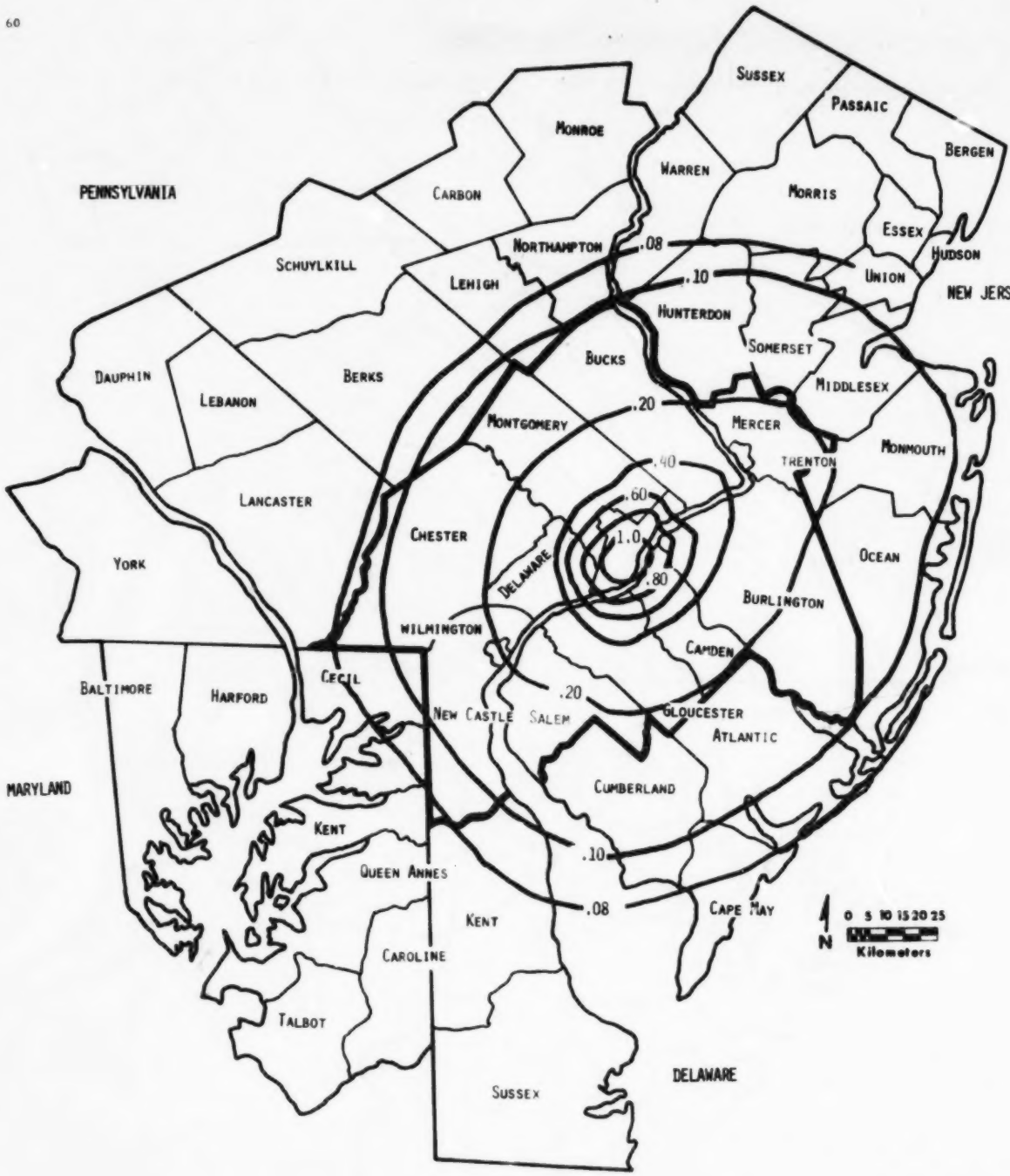


FIGURE B-5. THEORETICAL CO CONCENTRATIONS IN PPM: ANNUAL AVERAGE.

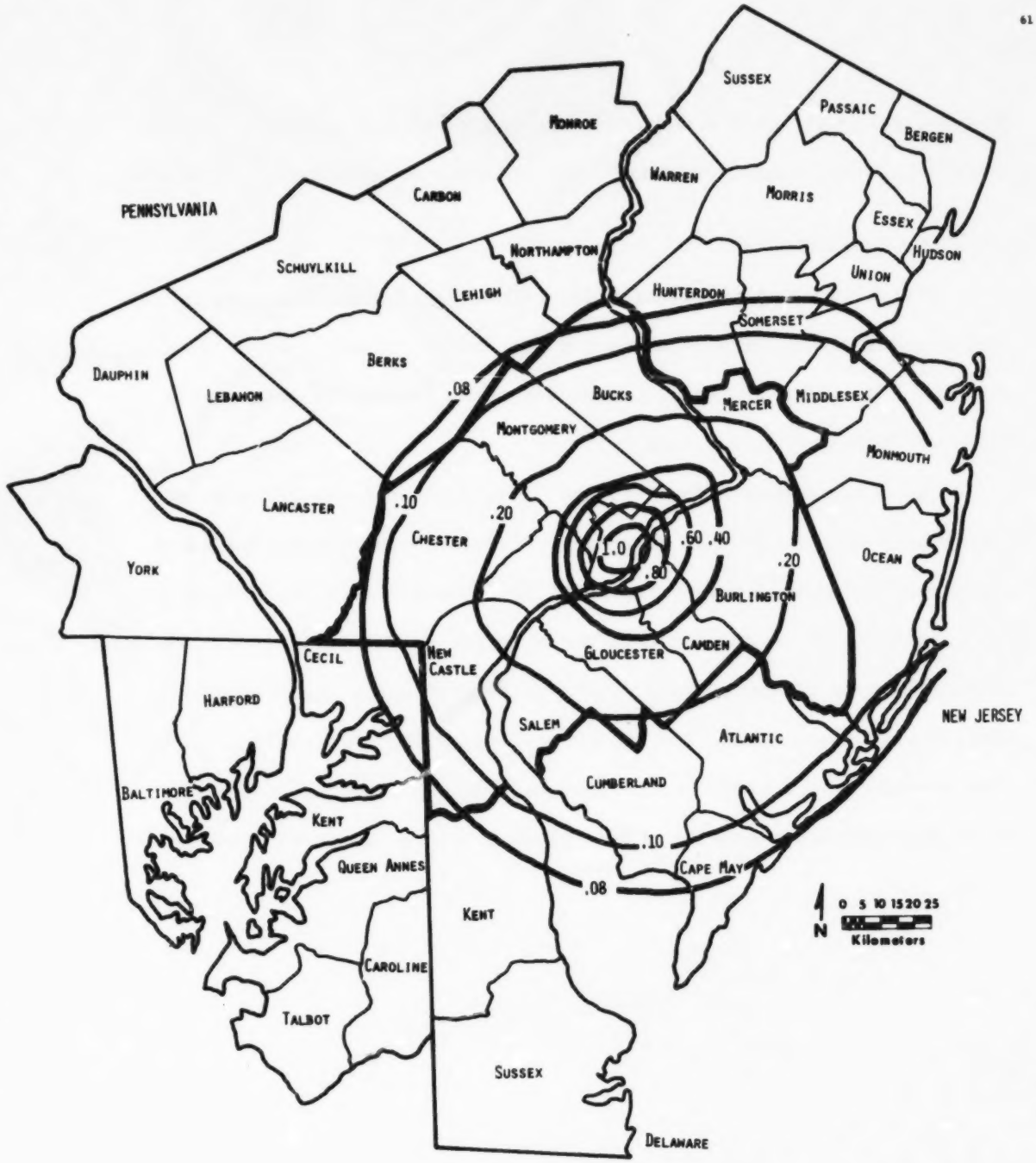


FIGURE B-6. THEORETICAL CO CONCENTRATIONS IN PPM; WINTER AVERAGE.

New Castle County, Delaware (contributing 9.8% of the pollution emitted according to the source inventory) are relatively free of high CO levels.

SUSPENDED PARTICULATES

Diffusion model results for the ground level concentrations of suspended particulates were obtained for the annual, summer, and winter seasons. The diffusion model output for these respective seasons are shown in Figures B-7, B-8, and B-9.

The emissions data input to the diffusion model was based on total particulate emissions. The suspended particulate concentrations (mean annual values) calculated by the model at the sites of three air sampling station's were greater than the measured concentrations at these 3 stations by a factor of 1.73. This is logical since the diffusion model fails to compensate for the deposition of the settleable particulate portion of the total particulate emissions. Figure 11, page 34 shows the calculated concentrations adjusted using the above factor.

FIGURE B-7. THEORETICAL PARTICULATE CONCENTRATIONS IN $\mu g/m^3$; ANNUAL AVERAGE.

FIGURE B-8. THEORETICAL PARTICULATE CONCENTRATIONS IN $\mu g/m^3$: SUMMER AVERAGE.

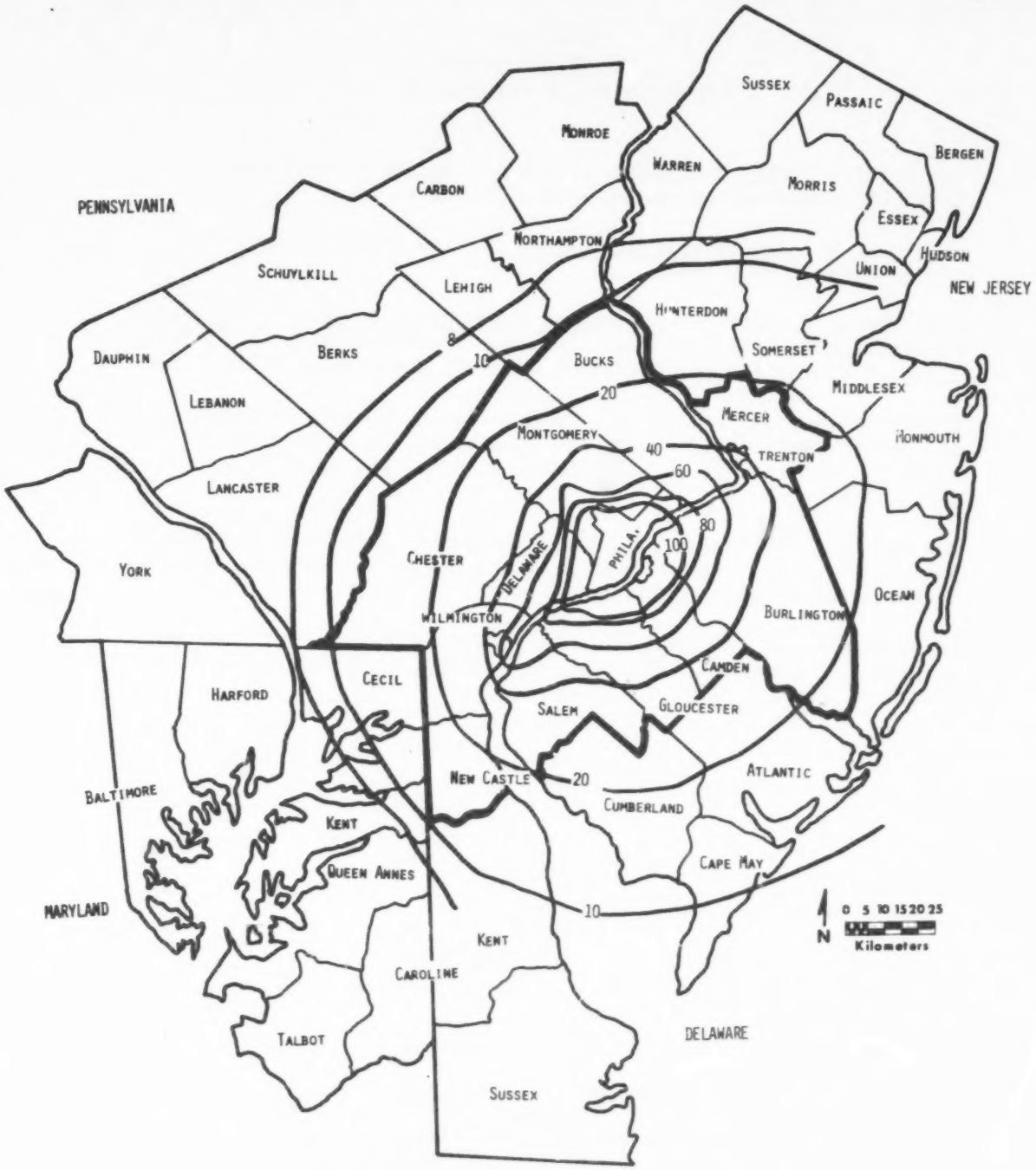


FIGURE B-9. THEORETICAL PARTICULATE CONCENTRATION IN $\mu g/m^3$: WINTER AVERAGE

## REFERENCES FOR APPENDIX B


1. Pasquill, F. "The Estimation of the Dispersion of Windborne Material", Meteorology Magazine, 90, 33-49, 1961.

2. Pasquill, F. Atmospheric Diffusion, Van Nostrand Co., New York, New York, pp. 190, 1962.

3. Public Health Service, Workbook of Atmospheric Dispersion Estimates, Publication No. 999-AP-26, Environmental Health Series, U.S. DHEW, National Center for Air Pollution Control, Cincinnati, Ohio, 1967.

4. Martin, D. O., Tikvart, J. A. "A General Atmospheric Diffusion Model for Estimating the Effects on Air Quality of One or More Sources", Paper No. 68-148, 61st Annual Meeting, APCA, St. Paul, Minnesota, June, 1968.

5. Holzworth, G. C. "Mixing Depths, Wind Speeds and Air Pollution Potential for Selected Locations in the United States", J. Appl. Meteor., No. 6, pp. 1039-1044, December 1967.

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## APPENDIX C. DEMOGRAPHIC DATA

This appendix consists of tables and charts showing various parameters of the metropolitan Philadelphia urban area. Some of this data is referred to in the body of this report, and some is not. All has relevance to the tri-State metropolitan area and is included in this report for possible future use.

Table C-1. Metropolitan Philadelphia[1]
AIR QUALITY CONTROL REGION

| County | Bucks | Chester, Pa. | Delaware, Pa. | Montgomery, Pa. |
|---|---|---|---|---|
| County Seat | Doylestown | West Chester | Media | Norristown |
| Basic Trading Area | Philadelphia | Philadelphia | Philadelphia | Philadelphia |
| Major Trading Area | Philadelphia | Philadelphia | Philadelphia | Philadelphia |
| Land Area (Sq. miles) | 617 | 760 | 185 | 491 |
| Population (1950) | 144,620 | 159,141 | 414,234 | 353,068 |
| (1960) | 308,567 | 210,608 | 553,154 | 516,682 |
| est. (1968) | 357,000 | 255,000 | 598,000 | 605,000 |
| Households (1968 est.) | 96,500 | 68,200 | 169,400 | 171,900 |
| Total Retail Trade 1966 ($1000) | 519,723 | 311,412 | 797,229 | 1,045,169 |
| Shopping Goods Sales 1966 ($1000) | 60,246 | 31,485 | 139,136 | 264,272 |
| Food Store Sales 1966 ($1000) | 124,106 | 80,925 | 230,412 | 257,893 |
| Drug Store Sales 1966 ($1000) | 14,738 | 8,717 | 28,755 | 30,312 |
| Passenger Car Registrations | 146,780 | 91,990 | 231,230 | 233,940 |
| Total Wholesale Trade (1963)($1000) | 116,309 | 185,413 | 525,900 | 2,163,610 |
| Manufactures (1963) | | | | |
| Total Employees | 35,123 | 25,784 | 53,462 | 82,229 |
| Value Added ($1000) | 522,460 | 329,830 | 535,658 | 984,913 |
| Agriculture (1964) | | | | |
| Number of Farms | 1,474 | 2,339 | 185 | 1,347 |
| Total Value of Products Sold ($1000) | 20,173 | 44,485 | 3,961 | 15,428 |

Table C-2. Metropolitan Philadelphia
AIR QUALITY CONTROL REGION[1]

| County | Philadelphia Penna. | Burlington N. J. | Camden, N. J. | Gloucester N. J. |
|---|---|---|---|---|
| County Seat | Philadelphia | Mt. Holley | Camden | Woodbury |
| Basic Trading Area | Philadelphia | N.Y., N.Y. | Philadelphia | Philadelphia |
| Major Trading Area | Philadelphia | N.Y., N.Y. | Philadelphia | Philadelphia |
| Land Area (Sq. miles) | 127 | 234 | 221 | 329 |
| Population (1950) | 2,071,605 | | 300,743 | 91,727 |
| (1960) | 2,002,512 | | 392,035 | 134,840 |
| est. (1968) | 2,040,000 | 305,000 | 450,000 | 160,000 |
| Households (1968 est.) | 627,700 | 74,400 | 128,600 | 44,700 |
| Total Retail Trade 1966 ($1000) | 2,992,611 | 302,864 | 715,644 | 173,887 |
| Shopping Goods Sales 1966 ($1000) | 748,689 | 49,300 | 180,251 | 13,887 |
| Food Store Sales 1966 ($1000) | 703,098 | 77,914 | 164,243 | 50,795 |
| Drug Store Sales 1966 ($1000) | 100,841 | 7,042 | 17,966 | 4,795 |
| Passenger Car Registrations | 604,270 | 75,410 | 166,810 | 56,860 |
| Total Wholesale Trade (1963) ($1000) | 6,100,499 | 116,697 | 858,031 | 185,897 |
| Manufactures (1963) | | | | |
| Total Employees | 264,893 | 17,505 | 44,491 | 12,320 |
| Value Added ($1000) | 2,779,004 | 204,746 | 491,827 | 183,194 |
| Agriculture (1964) | | | | |
| Number of Farms | 43 | 1,070 | 230 | 942 |
| Total Value of Products Sold ($1000) | 666 | 19,375 | 4,646 | 20,918 |

Table C-3. Metropolitan Philadelphia[1]
AIR QUALITY CONTROL REGION

| City | Camden | Trenton | Wilmington |
|---|---|---|---|
| County | Camden, N.J. | Mercer, N.J. | New Castle, Del. |
| Basic Trading Area | Phila. | Trenton | Wilmington |
| Major Trading Area | Phila. | Phila. | Phila. |
| Ranally City Rating | 2-S | 2-A | 2-A |
| Economic Activity Code | Mm (D) | Mm | Mm |
| Population: 1960 | 117,159 | 114,167 | 97,827 |
| est. 1968 | 110,000 | 102,000 | 87,000 |
| Households (est. 1968) | 33,000 | 30,000 | 27,900 |
| Total Retail Trade (1966) ($1000) | 192,005 | 231,230 | 275,746 |
| Shopping Goods Sales (1966) ($1000) | 47,421 | 87,484 | 63,697 |
| Total Wholesale Trade | 541,766 | 199,456 | 616,779 |
| Manufactures: | | | |
| Total Employees | 31,440 | 17,660 | 23,944 |
| Value Added ($1000) | 355,155 | 214,432 | 108,835 |

Table C-4. Metropolitan Philadelphia[1]
AIR QUALITY CONTROL REGION

| County | Berks | Lancaster | Lehigh | Northampton |
|---|---|---|---|---|
| County Seat | Reading, Pa | Lancaster, Pa. | Allentown, Pa. | Easton, Pa. |
| Basic Trading Area | Reading | Lancaster | Allentown - Bethlehem/Easton | |
| Major Trading Area | Phila. | Phila. | N.Y. | N.Y. |
| Land Area (Sq. miles) | 864 | 944 | 347 | 374 |
| Population (1950) | 255,740 | 234,717 | 198,207 | 185,243 |
| (1960) | 275,414 | 278,359 | 227,536 | 201,412 |
| est. (1968) | 288,000 | 286,000 | 232,500 | 207,500 |
| Households (1968 est.) | 91,100 | 82,700 | 70,900 | 62,500 |
| Total Retail Trade 1966 ($1000) | 435,697 | 465,656 | 433,361 | 263,129 |
| Shopping Goods Sales 1966 ($1000) | 89,532 | 80,200 | 129,134 | 46,840 |
| Food Stores Sales ($1000) | 101,383 | 99,787 | 85,498 | 82,006 |
| Drug Store Sales 1966 ($1000) | 8,368 | 8,767 | 8,823 | 8,218 |
| Passenger Car Registrations | 123,740 | 127,810 | 94,840 | 102,520 |
| Total Wholesale Trade (1963) ($1000) | 260,455 | 362,446 | 388,018 | 117,341 |
| Manufactures (1963) | | | | |
| Total Employees | 50,719 | 47,878 | 37,031 | 46,065 |
| Value Added ($1000) | 429,460 | 532,634 | 307,143 | 407,008 |
| Agriculture (1964) | | | | |
| Number of Farms | 2,821 | 6,247 | 1,120 | 1,078 |
| Total Value of Products Sold ($1000) | 35,038 | 109,107 | 12,877 | 12,221 |

Table C-5. Metropolitan Philadelphia[1]
AIR QUALITY CONTROL REGION

| County | Atlantic | Cumberland | Hunterdon | Ocean |
|---|---|---|---|---|
| County Seat | Mays Landing, NJ | Bridgeton, NJ | Flemington, NJ | Toms River NJ |
| Basic Trading Area | Atlantic City | Vineland-Millville | New York, NY | New York, NY |
| Major Trading Area | Phila. | Phila. | N.Y. | N.Y. |
| Land Area (Sq. miles) | 569 | 599 | 434 | 642 |
| Population (1950) | 132,399 | 88,597 | 42,736 | 56,622 |
| (1960) | 160,880 | 106,850 | 54,107 | 108,241 |
| est. (1968) | 185,000 | 128,000 | 66,000 | 162,000 |
| Households (1968 est.) | 59,700 | 37,300 | 19,100 | 48,400 |
| Total Retail Trade 1966 ($1000) | 337,121 | 188,104 | 90,771 | 254,929 |
| Shopping Goods Sales 1966 ($1000) | 78,664 | 47,762 | 23,055 | 75,870 |
| Drug Store Sales 1966 ($1000) | 9,805 | 4,158 | 1,834 | 7,099 |
| Passenger Car Registrations | 75,680 | 52,560 | 28,570 | 56,980 |
| Total Wholesale Trade (1963) ($1000) | 132,338 | 105,672 | 41,546 | 70,535 |
| Manufactures (1963) | | | | |
| Total Employees | 8,740 | 20,903 | 5,138 | 3,556 |
| Value Added ($1000) | 97,963 | 177,979 | 53,397 | 37,879 |
| Agriculture (1964) | | | | |
| Number of Farms | 649 | 1,035 | 1,031 | 345 |
| Total Value of Products Sold ($1000) | 14,673 | 24,829 | 16,213 | 6,573 |

Table C-6. Metropolitan Philadelphia[1]
AIR QUALITY CONTROL REGION

| County | Warren | |
|---|---|---|
| County Seat | Belvidere, N.J. | |
| Basic Trading Area | Allentown-Bethlehem/Easton | |
| Major Trading Area | N.Y. | |
| Land Area (Sq. Miles) | 362 | |
| Population (1950) | 54,374 | |
| (1960) | 63,220 | |
| est. (1968) | 72,000 | |
| Households (1968 est.) | 21,500 | |
| Total Retail Trade 1966 ($1000) | 99,785 | |
| Shopping Goods Sales ($1000) | 6,874 | |
| Food Stores Sales 1966 ($1000) | 29,310 | |
| Passenger Car Registrations | 31,850 | |
| Total Wholesale Trade (1963) ($1000) | 40,317 | |
| Manufactures (1963) | 10,655 | |
| Total Employees | 10,655 | |
| Value Added ($1000) | 119,128 | |
| Agriculture (1964) | | |
| Number of Farms | 654 | |
| Total Value of Products Sold ($1000) | 13,113 | |

## REFERENCES FOR APPENDIX C

1. Rand McNally Commercial Atlas and Marketing Guide, 99th ed., Chicago: Rand McNally and Company, 1968.

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